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By-Margolin, Joseph B.; Misch, Marion R.

EDUCATION IN THE SEVENTIES, A STUDY OF PROBLEMS AND ISSUES ASSOCIATED WITH THE EFFECTS OF COMPUTER TECHNOLOGY ON EDUCATION.

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To aid policy development for the utilization of computers in education, a panel of 10 scientists and educators formed a traveling seminar that actually inspected the state of the art of computer-assisted instruction at seven research and development centers throughout the U.S. The panel agreed on four principles. First, a systematic approach to the achievement of educational goals is required. Second, the development of models is useful for the synthesis, presentation, and testing of new systems. Third, the computer has vast potential as an administrative aid to education. And finally, the panel agreed that the introduction of computers into the schools to deal with clerical and administrative problems will lead to their use in an instructional capacity. The main area of disagreement was over the nature and specific objectives of the optimal CAI system. In addition, the panel expressed a general concern over the effect of the computer on human values. Topics covered in the panelists' papers are learner needs and systems requirements, the hardware-software disparity, decision making in education, social change, urban education, public policy, school architecture, economics of education, teacher education, educational administration, computer languages and applications of the computers in the classroom, in the library, in research, and in counseling. (LH)

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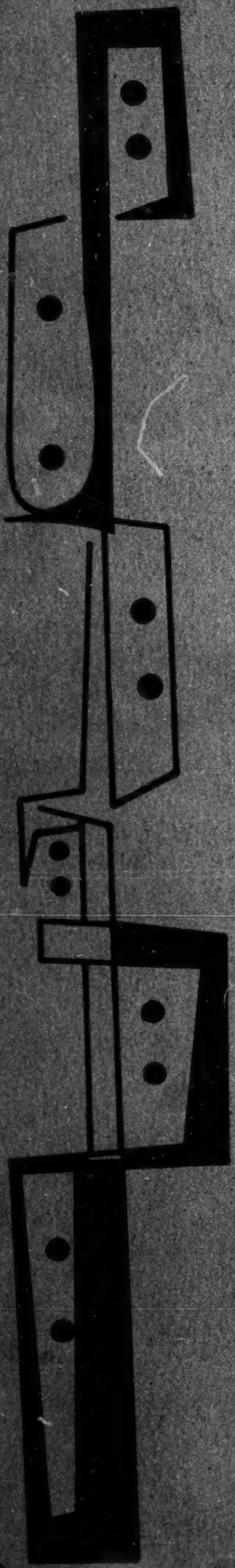

EDUCATION

IN THE 70's

A Study of Problems and Issues associated with the Effects of Computer technology on Education

Educational Policy Project
The Program of Policy Studies
The George Washington University
Autumn — 1967

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To the representatives of industry, government, and education who took part in the briefing of the panel and gave us the necessary start;

To the members of the panel whose richness of experience, creativity, and skill made the achievement of the project possible.

We also want to thank Mr. N.M. Head and Mr. A.C. Windham of the Office of Sponsored Research, The George Washington University, for their guidance; Miss Christine McLean and Mrs. Barbara Higgins for their untiring assistance, and Mrs. Diane Bugash for the design of the cover.

Joseph B. Margolin
Marion R. Misch

October 1967

FINAL REPORT

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OFFICE OF EDUCATION
BUREAU OF RESEARCH

EDUCATION IN THE SEVENTIES

Submitted by

Dr. Joseph B. Margolin
Responsible Investigator

Miss Marion R. Misch
Research Associate

Project Officer

Dr. Glenn Boerrigter

Panel Members

Dr. Ray C. Carpenter
Dr. Frederick Duhl
Dr. Russell Kropp
Dr. Hylan Lewis
Dr. Eugene McLoone
Dr. Wesley Meierhenry
Dr. Donald Cook
Dr. Alexander Schure
Mr. Charles Thomsen
Dr. Elizabeth Wilson

Professional Staff

Mrs. Judith Leitner
Mrs. Phyllis McDonald
Mr. Gary Larsen
Miss Christine McLean
Mrs. Barbara Higgins

EM 000 233

Educational Policy Project
Program of Policy Studies in Science and Technology
The George Washington University

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
OFFICE OF EDUCATION

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Introduction

The current crisis in education is multi-determined. New demands and new resources are converging on this normally conservative segment of our society, at a pace never before encountered. The pressures on education include:

1. The demand for education of an ever widening population reaching almost from the cradle to the grave.

2. The paradoxes of demands for greater specialization and greater general adaptability to the tremendously increased rate of change in the economy, coupled with the requirement for rapid retraining and more general education.

3. The need for more comprehensive, less narrow education permitting great flexibility of the individual and fuller participation in our society.

4. That we keep pace with the rapid social changes and the increases in mobility and fluidity of society.

5. The pressure for increased efficiency, centralization, and even more knowledge.

At the same moment, the technological advances present education with the promise of a vast new capacity.

A. The computer with its acknowledged ability to improve educational management also offers the potential for improvement in research and instructional capability.

B. Instructional television and a host of other devices and systems including the videocorder widen the media available and the range of modalities to be involved in education.

C. The advent of the systems philosophy and approach.

D. The era of the sputnik in which education's relationship to society and industry is given one of its periodic boosts.

In the face of these complementary yet somehow competing forces a third force can be heard. It is the fear of depersonalization, alienation, and loss of privacy already active in our mass society and represented, to so many, by the computer and the punched card. Perhaps we are simultaneously experiencing a rebirth of humanism and individuality as a reaction to this pressure.

These several forces impinging on education produce a policy crisis. With great pressures to produce with the potential capability available, but with great dangers inherent in both moving forward and standing still, education and society face a series of decisions. It is not yet clear that we have the methodology with which to make these decisions.

This report represents an effort to classify some of the issues and problems involved in this policy crisis. Lest it be overly diluted it was directed to the use of the computer in education and even more specifically to computer assisted instruction. With this process as a focus we will deal with the many areas in education and society that are touched by CAI and that it will in turn effect.

The Research Instrument and the Traveling Seminar

In the service of policy development in the utilization of the computer in education a panel of scientists and educators were assembled. These included the president of a university, two deans of schools of education, a sociologist, an architect, two psychologists, two educators, a director of curriculum development, a psychiatrist, and an economist. From another viewpoint, they reflected competence in engineering, education, research, administration R & D in the educational media, school design, program development and promotion, systems analysis, programmed instruction, intergroup relations, child development, etc.

After three days of intensive briefing, the seminar members set out on a weeklong aerial tour of five centers of research and development in CAI. Subsequently two more centers were visited. The program and itinerary of the briefing and of the survey trips are described in another section of this report. The texts of several of the briefing papers are included in the report as well.

Each of the seminar members then prepared an article dealing with his view of the problems and issues facing education in its use of the new technology. The panelists made projections describing the effect of technology on education in the 1970's, and offered recommendations on how to anticipate or deal with some of these problems.

The interplay of skills, personalities, experience, and views of life resulted in knowledgeable and critical discussions of many aspects of the problem area. They also produced a series of creative and well founded articles that penetrate to the core of many of the issues that we must face and offer a constructive approach to most of them.

The articles are written in three languages or on three levels of discourse. 1) The language of technology; 2) The language of the behavioral sciences; 3) The language of humanities and values.

We began to think in terms of languages as we faced the problems associated with computer languages that are so determining of the content and structure of the program. The languages we have listed above are no less determining. However, it is interesting that each of our authors discourses eloquently in the three languages.

This chapter and others by the responsible investigator are devoted in part to weaving a tapestry of the ideas, predictions, and recommendations offered by the consultants, and in part to introducing those additional thoughts and data assembled by the two staff members during the course of the project. Generally, we will avoid repetition of the material in the articles except for the purpose of highlighting it or linking congenial or related ideas.

The panel agreed in several areas. 1) It was generally assumed that a systematic approach, probably systems analysis, was necessary for education to achieve the advances required of it. 2) The development of models was generally agreed upon as a useful device for the synthesis, presentation, and testing of new systems. 3) There was general agreement that the computer has vast potential as an administrative and management aid to education. 4) It was also the concensus that this management use will provide the base for the introduction of instructional capability. The group was impressed with the instructional potential of the computer if certain criteria were met and if specific objectives were sought. It is in these qualifications and requirements that the panel disagreed most dramatically and most frequently. That computers would be used for instruction seemed to them inevitable; how they should and would be used was the bone of contention. 5) There was a general concern with the effect of the computer on human values and the more pervasive question of, "who will control the 'Knowledge Machine'?".

There were a few areas of disagreement or non-agreement that should be noted as background. There was little concensus on the objectives of those introducing CAI or on the nature of the optimal system. Some authors perceived a "takeover" by the computer with the teacher replaced, and the learners devoting most of their time to a computer terminal in a computer controlled school system. Others expected a slow introduction of the computer, and CAI with limited objectives playing only one part in the overall orchestration of education.

Rather than engage in the "way out" thinking that is so common and so tempting, the group attempted an orderly approach to the future. This is not to say that the panelists were incapable of "wild blue yonder" kinds of creativity. On several occasions the projections reached for the complete abandonment of the school and the use of home terminals or even wrist computers linked by microwave and satellite to a central universal storage. Advances in biochemistry and neurophysiology were joined with computer capability for some truly science fiction thinking. It was agreed that we were nevertheless bound in such thinking by the limitation that Henry Villard (ref. Tech. Innov &

Society p. 163) attributes to "the kindly chap who worried more than a hundred years ago, as to whether the inhabitants of the 20th century would be able to read at night because of the dwindling supply of sperm oil."

As a result, the panel tended to begin with the State of the Art. However, it was the state of the art as a point of departure. Any serious projections must provide time for development and "tooling up". Thus we begin where we expect the computer in education to be two or three years from now. Insofar as organizational and economic problems are concerned, we can do little better than begin today. So beset are we with alternatives and directions that the branching must begin with now. Compelling as is the idea of education in the seventies and eighties, it is nevertheless true that the future begins tomorrow and it is a product of yesterday and today. We have a continuing obligation to, and dependency on, today's school system and education. Furthermore, in order to make any long-range or even intermediate projections we must have an understanding of the needs, resources, and dynamic processes currently engaged.

Thus the goals of the project are to understand what forces will lead to "Education in the 70's" and what processes are likely to operate, depending on the decisions we make.

The state of the art must be presumed to be the state of the art of education in which CAI and other technology are but parts of the system. They are considered to be tools of the educator not masters, for ultimately the values, the directions, and the decisions must be human ones. Different people may prefer different values, directions and decisions, but the purpose of the art remains to convey a favorable environment for learning. On this we appear to agree, and with this we can make a beginning.

BRIEFING

Pre-Seminar Briefing

During a two-day briefing prior to the Travelling Seminar, the panel was addressed by representatives from government and academia on issues related to the study.

Dr. R. Louis Bright
Associate Commissioner for Research
United States Office of Education

Dr. Louis B. Mayo
Vice President for Advanced Policy Studies and
Director, Program of Policy Studies in Science and Technology
The George Washington University

Dr. Glenn Boerrigter
Research Coordinator
Division of Elementary and Secondary Research
United States Office of Education

Dr. William M. Richardson
Assistant Director, Academic Computing Center
United States Naval Academy

During the briefing, representatives from several major industrial organizations spoke about the present directions and problems in the implementation of CAI. All the companies involved are engaged in research, development and marketing in the field. All are deeply concerned with the techniques of education evolving with the assistance of the new technology.

The following is a list of these companies, and their representatives.

General Learning Corporation	---Mr. Daniel Lewis Director Technology Services Washington, D. C.
I.B.M. Corporation	---Mr. Leonard Muller Director of Instructional Systems Development Armonk, New York
	Dr. Louis Robinson Director of Educational Affairs Armonk, New York

Philco-Ford Corporation	---Mr. Marvin Gelman Systems Analysis Section Willogrove Plant Philadelphia, Pennsylvania Mr. Thomas Timlin Advanced Engineering and Research Blue Bell Plant Philadelphia, Pennsylvania
Radio Corporation of America	---Dr. Carroll V. Newsome Vice President, Education New York, New York
Responsive Environment Corporation	---Dr. John H. Martin Senior Vice President Englewood Cliffs, New Jersey
Westinghouse Learning Corporation	---Mr. Henry K. Skeel Director, Administration & Finance New York, New York
The Xerox Corporation	---Mr. James L. Rogers Senior Scientist Education Program Planning and Development New York, New York

The briefing sessions were recorded. With the permission of the speakers, five are reproduced here to demonstrate the range of research and development work, the divergent points of view and the common concerns of industry in this aspect of education.

Early in the development of the project, it was realized that not all of the participants would be equally knowledgeable about computer technology. It was necessary to find a means of orienting the panelists so that a common baseline of information would be made available to all. Other criteria for the presentation required that it hold their interest and that it be generalizeable to the broad field of computer technology. Books and films were considered and found wanting. Finally, after considerable consultation we discovered Dr. Louis Robinson of the IBM Corporation who agreed to provide the necessary "non-commercial" orientation. It need only be said that engineers and educators alike sat in rapt attention during this talk Its value to the neophyte was readily apparent, however even the informed welcomed and learned much from this lucid, systematic, and informed presentation.

Dr. Louis Robinson

Most of the more traditional disciplines, maybe all of them, have at least some superficial structure. The classical disciplines have a very solid structure. You need only think back to the introductory courses and use the course outline as a guide to the format of the subject.

Computers are not, have not matured to the point where the computer sciences have the underlying theoretical bulwark that would allow that kind of easy and well formatted structure. I think if two different people were to try to describe what computers do, they might well approach them from two different points of view. Indeed, from very personal points of view. And I am sure I will lapse into that now and then myself.

Let me say very briefly how I think I must approach it. I will make some remarks about the computer industry itself, so that you get a feeling for the magnitude both of what has happened and of some of the directions, the technological directions and some of the applications and use directions that computers are being put to. I would like to discuss with you a very fundamental and basic notion in computer sciences. The digital computer as we now know it, comes in literally hundreds of different models in a wide variety of sizes. When one looks at one extreme or another, the two computers can look superficially very, very different. Fundamentally underlying this device is a very stable and relatively straight forward system design, which is common to and peculiar to all digital computers. I would like to discuss that, discussion may open up ideas that will be fruitful in the future. And then lastly, I would like to spend some time talking about what is in fact the most difficult part of computer science, and that is the notion of communicating with computers, how do we tell computers what we want them to do, and how do we control them, how do we measure their flexibility, their applicability to a wide spectrum of problems? Sometimes that is called programming, I think, as you'll see, it is a little more. That question is a little broader than that. Let me say that the reason I want to devote our time that way, and spend maybe an hour or three quarters of an hour on the question of programming is that it turns out pragmatically that programming is more typical of the computer industry than the hardware, which is the thing you physically see. And incidentally, I might say that the thing that computer corporations make money on, for example, Booz, Allen and Hamilton made a study just before the end of last year on computer users, and they concluded that although the range was from twenty-five to fifty per cent, that on the average, thirty-seven per cent of a computer user's budget goes to the hardware equipment, of the thing you call the computer. Thirty-seven per cent - a third. And the rest of the moneys go to supporting the programming staff, the operational staff, and the environment, and these overwhelm the dollar investment in the thing that is the computer itself. The computer itself represents, has for some time now, represented economically only a small part of the total computer systems problem. So to draw too much on the elegances of some of the hardware, I think, would represent a distortion in an introductory discussion of what the true picture is.

I have drawn a few charts from which I thought we could talk. These are purposely very generalized, I don't attest to the accuracy of the curves. But they give you, I think, a picture of the trend. This is a representation of the number of computers in the world; in 1956 there were about a thousand, in 1950 there were something like six or ten, and now there are, in 1966, 35,000, and I think the count today is something like 44,000. The projection for 65,000 in 1970 and very likely 85,000 or a 100,000 maybe by 1975. These are digital computers. Let me just say a word to distinguish digital computers from analog computers. Everything I will be discussing today refers to digital computers. Those are devices that manipulate discrete digits, numeric quantities. Analog computers, on the other hand, in quantity far outnumber the digital variety. There are literally millions of analog devices. For example all the slide rules in the world are analog devices, thermometers are analog devices, and more important than those devices is the notion of electronic analog devices, which was born after the war as digital computers were, and which have achieved a similar degree of acceptance and popularity. Electronic analog devices are built out of amplifier circuits in such a way as to simulate the behavior of addition and multiplication, and the other arithmetic functions I am talking about here, but in a fashion that relates electrical, physical quantities to the quantative things you want to measure in a particular problem. Most commonly, voltages and voltage rises and drops and potential differences are analogous in an analog computer to the physical dimension you are trying to deal with, whether it be atmospheric pressure in a weather forecasting situation, or scores in an intelligence test, it makes no difference.

One manipulates an analog computer by adjusting these voltages, by wiring the electrical circuits to be interconnected in a fashion that is electrically analogous to your analytic representation of the physical phenomena, whatever that may be. This presumes you already have a mathematical, or analytic representation of the problem that you want to process, and that someone, an engineer usually, has built this into the analog circuitry. And now by simply manipulating the dials, not unlike what you do when you adjust a television set, you cause the response of the device, to indicate to you by indicating measures of voltages or resistance, what the numeric representation is of the answer to the problem you have posed. Now that numeric representation is going to be represented by the movement of a dial on a voltage meter, for example. That can be made very accurate, sometimes as accurate as a tenth of one per cent. But never absolutely accurate, because it has all the vagaries of reading a dial, of moving a dial. A characteristic of analog computers is that they never are absolutely accurate but they need not be in the applications in which they are used. On the other hand, a characteristic of digital computers is that they can be made as mathematically accurate as you choose. You can make it accurate to ten decimel places, or ten thousand decimel places, or whatever you choose; but you'll see there is a price one pays for that in difficulty, in computer power. But this notion that digital computers accurately manipulate digits, whereas analog computers analogously manipulate electrical quantities almost dictates the different ways in which they are used. In business applications, in scientific applications where mathematical preciseness is an end in itself, digital computers are invariably used. In applications like wind tunnel simulations, where in the first place one is after physical approximations to reality, in an analogous fashion analog computers are almost invariably used. Analog computers are installed in aerospace industries and things of this sort, whereas digital computers are installed without regard to the technological work of the industry, because they are wherever people have to process data and information in a precise form, and the forms we are going to be talking about. This population has grown very rapidly, primarily because of a growing awareness that nothing new has been added to the digital computer. Some of my colleagues may worry about the quality of that statement, but in general, nothing new has been added to the logic in the design of digital computers, even from the very inception of digital computers after World War II. This growth is a recognition more of the power of digital computers, their flexibility, their applicability, than it is innovation in the design of digital computers. Now it is true that digital computers have come down greatly in price, they have become more readily available and physically more compact and therefore probably more acceptable to segments of the population. But, in the final analysis, this growth of acceptance is really a consequence of a very slow recognition of the power of the original tool and anything that is done today could have been done even 1951.

Dr. McLoone: "There is a difference certainly in storage capacity?"

"Yes, of course a difference exists in speed and capacity or power of machine. Any problem that can be done in even the world's fastest and most powerful machines today could have been done a lot slower, and therefore, much more expensively, on the original digital computer."

"Now, the size of the machines has dropped. A computer which in 1956 would have occupied 1,000 cubic feet, a room ten by ten by ten, which was about as big a room as you would have needed to house what in 1956 was the world's biggest and most powerful computer. At that same capability today, it can be housed in a box that is only ten cubic feet; that is the top of the table. Now that is not a testimony to the size of packaging of industrial designs, so much as it is a consequence of technological necessity. There is a problem here that I want to try to identify for you. One of the laws of nature that we accept is that the speed of light, the speed of electricity is a constant in nature. As you'll see when we design digital computers, what we essentially are designing are a set of switching circuits, which are housed in a box and interconnected by wires. Electrical impulses travel from one circuit to the other. Now these circuits take up physical space, and therefore one is physically separated from another. The speed of the computer, the inherent speed of the computer is directly related to the speed of switching circuits. The faster you can make those circuits operate, the faster you can make that computer. But if you need enough of them, and you do, and if they each take up a certain amount of physical size and you have to put them in a very, very large box. In 1956 a box that occupied half of this room. Then obviously one circuit, one way down in that corner is a rather great distance from the one that is located in this corner. Right? It can't be any other way. And the electrical pulses that may from time to time have to travel from that circuit over to this circuit takes, in the computer world, a very long time, even though they are travelling at the rate of 186,000 miles a second. A very long time. The result is while this pulse is plodding along, moving from that circuit over to this circuit, lots of time passes, like several millionths of a second, and if you went to great pains to make this circuit over here fast, so that it could switch in several billionths of a second, it is to no avail, because although when the pulse gets to it, it will switch over very rapidly, in several billionths of a second, it is going to take a long, long time, namely several millionths of a second for the signal to get there to tell it to switch in the first place, so why rush? And that meant that the total speed of the computer was limited not by the switching speed of the circuit, but by the distance of one circuit from another. So although people do want to build very fast switches, there is no way to make that signal get to the switch fast enough to exploit the speed of the switch. It became very important that the physical size of the computer shrink so that as you invent this faster and faster circuit, you could exploit that speed, that speed, by not losing the slight advantage in the transmission of signal time between circuits. And so even today, our problem in designing even faster machines that I will allude to, is closely related to the miniaturization of the equipment. This miniaturization is fortuitous from several points of view. It permitted the use of very fast circuits to be exploited, to be used in a meaningful way. As computers grew in logical size, I'm going to define that in a minute, then, as they grew in logical size, if they weren't being made miniature, instead of occupying half this room, they would have to occupy this whole building if we had to build them according to the specifications of 1950-1955. So that again, if we wanted a 1967 computer in 1957, with its size and logical capability, it would have been to be so large physically that by definition it wouldn't be fast, and if it isn't fast, it isn't powerful, and if it isn't powerful, we made it big for no purpose at all. So this is both a necessity and a blessing in a sense that this curve has moved in the direction, and is continuing to move in this direction."

We keep saying that machines get more powerful. You'll see as we go through this that it is very hard to define what you mean by power in a computer. It can mean a lot of things. I have a very elementary notion of how fast these are. You know and we will discuss how machines do certain things, how they add, they subtract, they multiply numbers, they divide numbers. To get a first approximation of what is power in a computer, one can ask how many numbers can a given machine add in a second? You know it can add a hundred numbers together in a second, that is one measure of speed or power, another machine can add a thousand numbers in a second, another measure of speed or power. It is a very crude and elementary measure of speed of power. Let us consider all the computers in the world, not a computer, mind you, but all the computers in the world, the digital computers which existed in 1956 were relatively few, but they were spread around the world. If theoretically you move them all into one room, and everybody was ready to go and the concertmaster said, "Now," and you stopped the stopwatch, and they all started working, namely, they all started doing arithmetic, they started adding and subtracting numbers, and then a second later you said, "Stop," and now you said how many numbers have we added together in a second, with all the computers in the world, all the computers in the world in 1956 would have been able to add about 500,000 instructions, 500,000 steps of arithmetic, in a second. That's how fast they were together. All the computers in the world now can add about 800,000 million billion instructions per second. There exists, for example, today, one computer, the fastest computer, which itself can add, can do ten million instructions per second, in one device, a relatively small device, that can do ten million instructions per second. By 1980, by 1975 even, there will exist based on what I perceive as the direction of technology, individual computers of relatively small physical size, individual computers, each one of which will be able to do not 10 million instructions per second, but of the magnitude of maybe 200 million instructions per second. Remember that all the computers in the world today can only do 8,000 million instructions per second. Look at how fast the thing is growing. You might as well ask, good heavens, what are all those instructions? How do people do them? Well, that's why I will discuss programming and instruction.

Now, going very fast is one thing and let me just suggest that there is another very pragmatic dimension in our economy, and that things can happen in very elegant ways, is one thing, but if they are preciously dear, very expensive, then it is only of academic interest that one can build such a device. It is true that these devices are very expensive. The machines that can do ten million instructions per second today cost in the magnitude of five or six million dollars each. I suspect that the machines that will be able to do 200 million instructions in the 1970's will cost $15 or $20 million each. As compared to the fact that this machine in 1956 would then only cost in the magnitude of $100 million, the cost of these things is in fact expensive. But their power goes up so rapidly that the costs of doing work goes down strikingly. So, for example, if I take a unit of measure, if I take one instruction, I would have to be talking about .000001 cent per instruction. So let's take a hundred thousand instructions. How much would it cost to do 100,000 instructions on any computer, roughly speaking? In 1956 as compared to now it turns out that 100,000 instructions cost about twenty-two cents, and those 100,000 instructions today cost about one cent to execute. So this, once again, raises a very provocative question. The overall price goes up bu the cost of doing 100,000 instructions goes down. You are dealing with many hundreds of thousands of instructions so a sizeable unit saving will follow.

When we talk about programming and how people use machines there is yet another trade off that has to be considered. We have already mentioned that one of the most important ingredients in the computing system is it memory. The size of the memory as measured by the number of bits that it can hold, if you will for the moment remember the number of digits, the number of decimel digits of zero, one, two, three up to nine, that it can hold. The size of that is very important, if a computer can only remember a couple of numbers, without knowing anything else it is clear that its logical capability is rather limited. So in time, memory size has grown very rapidly, until in 1956, for example, a very large computer would have been one whose memory could hold a couple thousand one digit numbers. Today, typical of the modern computer is one whose memory holds a million, two million numbers, in its main memory and yet hundreds of millions of other numbers in other memories that we will talk about. In the future that number will swell, and this curve is very likely heading in the right direction. The cost per unit memory, how much it costs to remember a digit, has gone down dramatically from, in these years, from roughly $1\frac{1}{2}$ cents per digit of memory down to two mills today is the average per digit of memory.

We have all seen photographs of computers and we've seen computers and you all know that they have various devices on them. They have magnetic tape, magnetic quality the power of the tape is measured like in your home tape recorder by the density on which you can record and speed with which you can read it are two obvious dimensions, as you can see they both are skyrocketing up. The technology has made it possible to record more and more information for an inch of tape and then read them or write them for that matter, at greater and greater speed. These record player like devices, magnetic devices, are pieces of cardboard shaped in the form of a disc, on the surface of which information is recorded just as it is on magnetic tape; it is actually surfaced with the same material. This is a rotating device unlike tape, which is a linear device. The dimensions that are important here are again how much information can I get on an inch of the disc, and how fast can I rotate the disc, so that I can read it back. The rate of speed of reading and the capacity of these numbers go up very rapidly. If it is necessary to make these devices small,they are being made small. If it is necessary to make them fast, they are being made fast. If it is necessary to make them record densely, they are being recorded densely. If it is necessary for economic reasons that the unit cost and price drop, then you'll see that this is happening very, very dramatically, so that the device becomes economically available to more and more people.

Now I want to talk briefly about the logical construction of these devices. What I suggest you do is to bear in mind a problem, any problem, whether it is an obvious problem in mathematics, or in accounting of keeping track of inventory control, of knowing that you have bins of devices in inventory. You know that from time to time you have additions to individual bins, to increase the inventory, and from time to time you have to make deletions from individual bins, as you satisfy orders, and you would like from time to time to know, for example, what the on hand inventory is. A very typical business problem. Another typical problem is salary computation, whether it is the regular weekly or monthly or hourly salary of employees, the computation is essentially the same. Take the unit salary and multiply it by the pay period, if your salary is weekly or monthly, that multiplier is the digit one, because that is what you get each pay period, and if you are an hourly salaried employee, you multiply by the number of hours worked, based on your time card, or the pay records. And now we all know what happens after you get that gross number. Now you start subtracting your union dues, you subtract your withholding. Then you calculate the FICA, the Social Security tax, based upon a regulated formula, a certain percentage multiplied by an income and kept track of, so that at some point if you earn enough money, they cease to withold. Maybe other deductions, bond deductions, a whole variety of calculations, all very strict formula. When you are all through, you subtract all the things you have calculated from the gross, and that tells you what kind of a check to write. That's quite a problem. Every industrial computer in the world does that problem.

Then there are other problems. There is the problem of translating Russian into English. This doesn't sound like the payroll problem, it doesn't sound like the inventory problem, but as we go through this, you will become persuaded that it is the same problem. Or it could be the problem of keeping track of a rocket or a satellite, or aiming a gun on a battleship, or forecasting weather, or calculating a statistical quantity, or preparing a concordance of Thomas Acquinas' writings. Whatever it is doing, the same machine is doing it. It may be a different model, but it is the same machine like all Chevrolets are the same machine. They are obviously mass produced, and they are the same logical devices. You got a radio in yours and I got the air conditioner in mine, but they are the same device. This is a tribute. All the computers in the world are basically the same computer, except for these trivial differences.

What is that base that makes them all the same? Well, whatever problem you have in mind, it has one characteristic, that because you know what that problem is, you know one other thing, the computer does not know what that problem is. The computer comes to you from the factory empty, blank, it has built in capabilities like a television set, but until you instruct it, until you put it in gear or turn it on or adjust the brightness, do something constructive, tell it what to do, give it information, it just sits there. It doesn't do anything, there is no capability inherent in the box. So the first thing is obvious, you've got to get information into it. If you can't get information into it, there is no way to design a machine that's automatically going to process the problem. So the first thing you want to do is get input into the machine. Now, how do we do that? There are an enormous catalogue of ways of getting information into a machine. The most prominent way is the punchcard. The punchcard is a paper block, you've all seen it, your paychecks are probably on it. A paper document arbitrarily divided into twelve rows, and eighty columns in this fashion. Information is recorded on it by punching out on a piece of equipment not unlike an electric typewriter, a hole that represents the information you want, so that if I lable this row one and the next row two, and the next row three and I want to say the number one, I simply punch the one position out in that column, so that column stands for the number one. And if in the next column I want to say the number two, I punch the two position. A very trivial coding technique.

What do you do to get the letter "A"? There are only twelve rows, obviously you take the twenty-six letters of the alphabet and you take the combinations of the two punches, you know, any two. You just pick two, and you say from here on those two punches represent the letter "A" and these two punches "B", and you make a code, like the Morse code. There exists such a code which is universally used as standard throughout the world so you can put any number, you know, one, two, or any letter in this code and indeed any special character you can think of like period, comma, colon, question mark, they all have a code, and there is a machine, a console, the keyboard looks identical to a typewriter keyboard with all those characters on it, and when you press the button for the letter "A" instead of the letter "A" printing, the card is there on the platen, if you will, and then just punches the appropriate holes. This becomes machine sensible. There are holes here, os, there are these devices that read the card, either photoelectrically sense the existence of the holes or more commonly with magnetic brushes sense the existence of the holes as these cards fly by at extraordinairly high speed. Thus information that is recorded on the card gets to the computer. This is one input device.

Another one besides cards is magnetic tape. An obvious extrapolation of the tape on the recording machine. It happens to be wider but it is otherwise the same kind of tape. The reel is bigger, if you want to get a lot more information on the tape, generally 2,400 feet long, but it is a big reel. It is Mylar magnetic tape like you have in your tape recorder and information is recorded on it in exactly the same way. As the tape, is moving in this direction, then at each point in time there is a right head, and as the tape moves by at each point in time, the tape is flocked to be divided into the logical roles. There is a code, a code similar to the earlier code. When you want to say the number one, magnetism is deposited on the magnetic surface, of the tape at that point, furthermore, whenever that tape is looked at by a machine, the existence of that spot means the number one. And if you want to say the number two, it would be a spot over here, (indicates) and number three would be a spot over here, and the letter "A" would be two spots over here, and in the same way a similar code exists on tape. Once I have the information on that tape, I can load it onto a device that unreels the tape and read the information off or I can write information on it. There are other devices that I have not listed. This idea was born out of the notion of a regular phonograph recorder. Phonograph recording discs happen to be shaped a little differently but that is not significant, and in the phonograph recordings invariable the information is recorded in the ups and downs of physical grooves, actual grooves, that's why you have to have a needle. On this, the idea is even simpler. You just take the reel of magnetic tape if you will, and unwind it and glue it down on the surface of the disc, and now you record on it exactly as you would on magnetic tape, it is magnetic tape, but because it is on a reel, it is laid down on the disc and you can record on both sides, front and back and you can have a stack of these. They are all rigidly mounted on a post, they can be mounted this way or that way, it doesn't make any difference any more because the thing that reads it, since it doesn't have to be in physical contact, doesn't have to ride in the groove like a phonograph record, it has to track like the head of a magnetic tape machine device, so now the laws of gravity don't go along with that. Some machines are mounted this way, and some are mounted this way. We code the information on the surface exactly the same as it is on tape. It's a magnetic medium, the coding is the same. There are magnetic heads that ride along the surface of this record as it rotates along underneath, and the information can be read or recorded. I think I have a sketch here of how that looks. (demonstrates) This could either be the magnetic tape or it can be the surface of the magnetic disc or magnetic devices. This is, of course, an enormous umbrella and an abstract drawing. This is a magnet. It is so miniaturized that literally hundreds of these can fit in the space of a quarter of an inch. And these are wire coils that are wrapped around the inside of the magnet. Now if you remember the rules of magnetic flux from high school, if we put a pulse of electricity in this coil, it has the effect of creating a magnetic flux in one direction at the base of this magnet. If we put a pulse at the other end it does the opposite. And you know if you take a magnet at home and put it near a nail and pick up a nail with the magnet and then take the nail away, that nail sometimes retains magnetic properties. It itself becomes a magnet and you can pick up another with it, even though the original magnet is now in another room. That is exactly what happens here. When you give a pulse to write something down, one of these code bits could be either the absence or presence of a bit. This magnet becomes magnetized and magnetism is infectious, if you will, and it magnetizes the magnetic surface of the tape, of the disc or what have you, and now this thing can move ahead, can rotate away, and later on when you want to read it, by putting a pulse on the other coil, you can detect whether or not that spot of magnetism is there. If it is, it means one code, and if it isn't it means another code. It is very easy to replay.

If you can wrap the magnetic tape on a disc, you can also wrap the magnetic tape on a drum. If I have a drum, I can take my reel of magnetic tape and wrap it around, so that the surface of this drum is now a magnetic surface. Mount the drum on an axis, and rotate the drum and put my magnetic reading heads over the surface of the drum, and now I can read and write on the surface of the drum, as the drum flys by underneath me as it rotates. So drums are commonly used in computers to record information permanently in a machine sensible form so that I can get it in and out of my machine. Think about these different media for just a moment. The cards always have in common that they record information in machine sensible form. The card is a unit, you know you have decks and you carry one in your pocket, and it serves a purpose. When you want to record long strings of information, like all your payroll information for the firm, or the school, or what have you, cards are obviously not the most convenient mode, so you can pack all that information that otherwise might be on thousands of cards, on a few feet of magnetic tape or maybe a few hundred feet of magnetic tape. Now suddenly I want to know how many, what the quantity of hubcaps for 1956 Chevrolets are in stock in the warehouse. That may be over here, someplace on the magnetic tape, three hundred feet away you know, so to read it, I have got to make my machine read that magnetic tape, skipping all that information until it gets to the point where it says hubcaps and then I can find out how many hubcaps I have. Now we are talking about super fast devices here. Tape is a very inefficient thing to search. You all have suffered the anguish of trying to find a spoken word or music on your magnetic tape. So what about the discs and the drums? Drums are becoming more and more visible, as the drum rotates, every time it turns around once, and you understand that these things are turning around at very, very fast speeds, for example, modern drums rotate at rates in the magnitude of 25,000 revolutions per second. I should have remembered the statistic that was something like, in one minute the drum makes more rotations than the propeller makes on an aircraft that flies from New York to San Francisco. Very, very fast devices. So that in a very few billionths of a second, the whole drum has passed by, the whole surface. There are many reading heads. The reading heads cover the entire drum. There is a line of them so in a few millionths of a second, everything on that drum has passed onto some reading head. So that if I want to store my inventory information I probably would be inclined to put it on a drum or a disc, which have the same characteristics because when I want that information, I want it quickly. And if it is on the drum, I have it almost immediately. It takes a long time, several millionths of a second, but that is better than waiting maybe two seconds to find it on the right place on magnetic tape. Several millionths of a second are very costly. A long time on a computer. There are certain kinds of information I would want to put on discs and drums and yet there are other kinds of information I would want to put on tape. If the kind of problem I have is sequential, for example, if I had just been given ten thousand Rorschach tests, and I have all the data of the Rorschach test on tape, and I now want to score, to rank and evaluate these tests on a computer, I really want to do them one at a time, I'm not going to be searching for Mary Jane's Rorschach test. I am just going to do the first one first and the second one second, and then when I'm all done I'm going to print my report. I have no necessity to skip around, and in that case tape is a much more efficient medium than these two devices, because after all, tape is virtually unlimited. Theoretically, it is unlimited. I can mount reel after reel after reel continuously in length. These devices, this drum, are physically limited by their physical size. When I've run out of space, it's the end of the game. So when I have long lists of sequential information, I put it on this medium. When I have limited information and I want ready access to it, I use the other medium. Hence, there is a necessity for several media, not just one.

Now there are many other types of input devices. Some of the more modern ones are very near the chart, for example, it is now possible to attach to the computer a cathode ray tube, a television like tube. And I can attach to the device what we call an electric pen. We used to call it an electric pen, really it is an electronic signal which serves the purpose of a flashlight. The device is slightly different from your home television set, but not much different. Behind the screen are photoelectric sensing devices, and when something is displayed on that screen, if I point to something on that screen and press a button, the photoelectric devices behind that screen senses that I pressed the button, and in a sense it knows where I pointed, because there are many devices distributed, so it knows I pointed here as distinguished from pointing there. I can communicate information to the machine in that way. For example, I may want to take an opinion poll. I have a thousand people sitting in front of these things connected to a computer. I give them a test or a list. It's a multiple choice kind of thing, and I list all the alternatives and in front of each alternative is a box. If it were a paper you would put an X in the box, and the responder points to the box that he wants to mark as his answer, but he doesn't put an X because it would not reach the computer. He points to it and a light is emitted, and the photoelectric eye senses that he pointed to that box, that particular box and that is now recorded someplace in the memory. It has been put into the computer. It's even possible to have voice recognition devices that can recognize spoken voices, special words like add, subtract, multiply and divide. So there is a very wide catalogue of input. Now if all we did is get information in, it would all go in and what would happen to it? It would drop through the bottom, and we don't want to do that. We built these devices because we want this information so we can do something with it - add it, subtract it, multiply it, compare it, do something with it. Build it up and process the information. But to process the information you can't get it glued to the machine, you've got to get it in and hold it there because it takes time to process, maybe only a few millionths of a second, but that is time. So you need more than just to get the information in, you must get it in and you must be able to retain it. Sometimes you have to retain it for a very long period of time, and hence we have the devices for memory. Now in one sense, some of these devices already represent memory. Once I record something on a punch card, it remembers on that card, it doesn't get erased, its a hole in the card. Or if I have written it on a piece of magnetic tape, it is remembered on the tape. But these devices are simply too slow to serve as the memory of the machine. These can be auxiliary memories, they can be aids to the memory, but they are too slow to be the memory, because if I want to remember things, I want to remember them right now, and you have seen that on tape it may be a second delay, maybe a second and a half away, a long time away. You have seen that on drums it may be as long as a couple of millionths of a second away. That's unacceptable. When we say memory, we mean it must be right there. How do we build memories that don't have the disadvantages of these devices? Well, the common way that memories are built today is with magnetic cores. I won't try to make engineers out of you, but let me just say a few words about this. These cores are in fact just as represented here pictorially, they are small, doughnut shaped, iron ferite devices which have special additives, they are highly magnetizable, easily magnetizable. They are prepared by a process of baking them in ovens, and they are very, very small. How small, I don't know how to describe. This picture is blown up ten million times. You can put a million of these cores in a thimble. I mean they are very, very small, miniature, super small. But they have that shape. They are laid out in a matrix, thousands of them, and wires are run, just as it is indicated here, through them. First in one direction, then in the other direction, and then finally in the third dimension you run wires through them. You can think of these, of one layer, as a plane of these cores. If I take a second plane, and lay it right on top, it's like a pancake. They are not physically touching. Incidentally, I want to make a comment that none of the stuff that I am talking about represents physical contact. Magnetic heads never physically touch the medium. They float over at a great distance from the medium, about a couple millionths of an inch, which is a great distance when measured in this technology. They never physically touch. These planes are not in contact either, and each layer is physically separated from the other although when you tack them together, you have pressed the thing so that they are separate, although very close.

These cores behave exactly like the magnetic surface of these mediums. When a pulse of electricity goes through in one direction, they get magnetized in one direction, and when the pulse goes through in the other direction, they get magnetized in the other direction, and by testing whether they aremagnetized one way or the other, you can record them again in the same coded fasion. This is infromation. Now, they have one advantage. When these cores are very numerous you can get millions of digits in one of these boxes. The obvious advantage of all these media is that every number in that storehouse of a million numbers is as readily available as every other number. There is no physical motion to get at something. Nothing has to rotate around each digit, whether it is at the low end or farther over here or in the middle or somewhere on the other end. Wherever the digit happens to be it is instantly available because all these things are wired together, you know, in a completely homogeneous fashion. So these core memories, for many years now, have served as the fundamental memory system of the computer. Now we have a way of getting information in and a way of remembering information we got in, but now we have to do something with it. The obvious thing we want to do is arithmetic. Now, do you want to add or subtract or multiply or divide, it turns out you want to do a lot more than that. A great deal more. In fact, it turns out that today when you run computers and you do this and you measure what is the machine in fact really doing, it is only doing arithmetic a very small percentage of the time. Twenty per cent of the time. What is it doing all the rest of the time? Well, if it is doing all the other things you find out what you wanted to do in order to solve the problem, for example, in the payroll problem, I am not sure I remember the right numbers myself now, but I think after you've earned $5,400.they stop withholding the social security number. How are you going to know that in a computer? From time to time you are going to check how much money an employee has earned and you are going to compare it to the number $5,400., and when it gets bigger than $5,400. you are going to stop the calculation. How do you accomplish that? Well, you want it to have a comparison capability. You want to be able to compare two numbers and decide when one number is bigger than another. That is a different capability than that of subtract, multiply and divide. You want to be able to distinguish between a number that is zero and not zero, because numbers which are zero play a very special role in processing problems. When we are through, listing all the things we want to do, the typical computer today has more than the four capabilities, add, subtract, multiply and divide. The typical computer has about a hundred capabilities. If we had these capabilities and we wanted to process problems, we should know that this isn't like a fishbowl, where you throw into the fishbowl lots of pieces of paper that say add, subtract, multiply, compare, $5,400.,and then mix them all up and hope that somehow the machine knows what to do and in what sequence. The machine doesn't know which things to do and in what sequence. It must be told which things to do in what sequence. It's one thing that they have the capability to do the things in the machine, it's another thing to be able to get the sequence control that you need. So besides having this arithmetic and logic capability, it has to have a control capability. You must be able to get the machine to do things in a specified sequence that in fact sometimes distinguishes the solution of one problem from another. And then lastly, of course, when you finish doing all this, you get the machine to do the arithmetic, and processing you want it to do, and then you get it to do it in the right way under control. All would be for naught if you couldn't get the answer, so you have to have the output devices. Sometimes the answer is displayed on the cathode ray in numbers or letters or whatever, sometimes it is displayed pictorially as a graph, as a curve, or you can obtain it pictorially as a representation of the thing that you are working on. It can be designing a bridge, it can be a representation of the actual bridge, or whatever it happens to be. Sometimes it is sufficient for your purposes to have the answer recorded on magnetic tape, or a disc or a drum, because you don't want to look at it, instead you want the computer itself to look at the answer at some future time, there on punch cards, like in the case of your pay checks. And very often you want it printed. The most populous kind of output device is the printer. In order to keep up with the speed of the computers, the printers have to be a little more than a typewriter, although typewriters are sometimes used. As a result a whole technology has developed for computer printing. These devices do not print a character at a time, like a typewriter. They print lines at a time, and sometimes even pages at a time, and they print very, very rapidly. Modern printers print a thousand lines a minute. This kind of thing could print the Sunday New York Times in a matter of a relatively few minutes. Faster than you can read. That's the list of capabilities.

Even with these capabilities we still face a problem. How can we communicate with the machine? Now, I just put up this note, you've seen this a thousand times, that is our language, our system, we use these numbers, there is nothing sacrosanct about these numbers. It turns out that the filing system is the same number system based on two symbols, zero and one, when you count the indicators here, count zero, I've just written up four digits for consistency's sake, but this is still zero, that is still one, instead of saying two since two is not a symbol, you represent two by the juxtaposition of the digit one. So this means one times two plus nothing left over. If I say to you the number 796, what I really mean is that this is 6 plus 9 times 10, 90, plus 7 times 100. That is what the juxtaposition of the digits means. In the binary system it is exactly the same thing except that instead of multiplying by ten you are multiplying by two, that means 1 plus 1 times 2, plus 1 times 4 plus nothing times 8. And so it reads number 7. Now, why do we use the binary system? Well, for several reasons. All electrical circutis and magnets, the whole notion of magnetism, has an off capability. Very important. All electrical switches are either on or off. So if we can represent information in a fashion compatible with the structure of electrical circuits, then we get a very simple encoding system. There is another advantage, and it comes from arithmetic. What you want to do when you build a computer is minimize the amount of circuitry you need to accomplish these logical functions. Now adding is a simple thing. Let's assume you built a device that can add two of these together to get the answer three. And you see you do. 1 and nothing is 1, and nothing and 1 is 1 and nothing and nothing is nothing. One and two are in fact three. Okay. The rules of arithmetic all hold. Now there is one very nice consequence of binary number system that plays a role in computing. You all know, I think, that when you want to do multiplication, the simple way to do multiplication is by repeated additions. If you don't happen to know how to multiply, and you want to multiply three times four, you can get the answer by saying 4 plus 4 plus 4, to get the results of multiplication by repeated addition. You can get the results of addition by repeated subtraction. So the whole trick now is to figure out a way to get subtraction by addition. If I can get subtraction by addition, I can do everything by addition, and that is very neat. It turns out that in the binary system, you can do subtraction by addition. It works this way. Given a binary number, given any number, either binary or a number in the decimal system, that I want to subtract one from the other, I can accomplish subtraction by a notion, a mathematical notion called complimenting. In our daily lives we don't us this method because it is very sophisticated, you know how to subtract. But if you didn't you would probably use complimenting. Let me just give you a few examples. One in the decimal system and one in the binary system. I want to subtract 72 from 98, we know how to do that, right, we know how to do that in our way. Another way to get results, is to take 98 and instead of subtracting 72, add its compliment, the compliment of 72 is what you get by looking at the difference between 72 and the number 99. It is always 99, that is constant. So I say the difference between 72 and 99 is 28, that's my trick. I have a little trick. When I say I can get the same result by adding 28 and then looking at the compliment of that. The result here is six and two, that is, twenty-six. So here I have eight and eight is sixteen, and nine and two is eleven, and I carry one; it is twelve, and my rule says you always forget about the higher digit. The result as you know is twenty-six, and it turned out to be twenty-six by this trick of adding the difference between the number I want to subtract and 99, instead of by subtracting the number. Now you say, what kind of a ridiculous trick is that? If you know how to get this, you already know how to subtract anyway. Why fool around? But, look at what happens in the binary system. I have a binary number, and I want to subtract another binary number, let us take one like 01101, it is very simple: one from one is zero, etc. Instead of doing the subtraction, I want to compute the compliment of that, the same trick I did here. But in the binary system the compliment is very easy to compute. The compliment is this number where every one becomes a zero and every zero becomes a one. It is very simple. So instead of subtracting, to get the right answer, in the binary system I just have to add this number. I just changed the zeros into ones and the ones into zeros. Now I do the addition, and I guarantee you that if you use the same rule you are going to get an extra one at the end, but that is just dropped, forget about it. If you follow that rule, the answer you get here will be identical to the answer you get there. Now although you know no sane person would use the trick in the decimal system, because it is just as hard as regular subtraction, you see the advantage in the binary system. This is a very simple trick to put into a machine. So that's how we use the binary system.

The problem now is how do we write programs. I have written down here a definition of programming, and in a very few minutes I am going to walk you through an exercise. Let me tell you what the exercise is. You all know that the Indians sold Manhattan in 1624 for $24, you know its now 1966 - 1967. We've come a full year, we've gone through 1966. An Indian may well ask what if the Indians could have sold the island and had taken the $24. and put it in a Manhattan bank, at compound interest, how much would that be worth today? Instead of wasting your wampum on firewater. You could say what is the average of all those years at 3.5% interest, you might say that this is a ridiculous problem, but all we are interested in really is the result. This compound interest problem comes up all the time and is typical of all statistical calculations. A sophisticated Indian not only asks what this $24. is worth at 3.5%, had it been invested all those years, but also what would have happened if it had been invested in a bank at 4.0%, or 3.6%, or 3.7%, you know, or whether he said I had decided to charge instead of $24., $25., $26., $24.01, what would be the difference if measured today? Now, instead of one I have millions of problems, they are all the same, they are repetitious of one another. How tedious to do this calculation. Very few people remember, there is a simple formula for this, you remember that the formula says that the amount of money that you earn at compound interest is equal to the principle that you put in in the first place, in this case it is $24., times 1 plus the interest all raised to the power of the number of periods and there with that mathematic number picture this exponent means you multiply the quantity inside the parenthesis by itself as many times as that number says. So for example, the number seven with a little three up here really means 7x7x7. Shorthand. Now, in algebra that is read this way: A is equal to B times 1 plus I to the Nth. Putting the numbers in, that means that the answer to our problem is simply $24 times one plus the interest rate of 3.5% which would be represented this way, all raised to the number of years that have transpired between 1624 and 1966, which is 342. Now you take this number, which of course is one times .035 and multiply it by itself 342 times, and multiply by $24., and that is how much money you would have. You can do this over and over again for each example. I told you that this was pretty tedious. And if you don't happen to remember that formula, you might be stuck. Except if you do it this way. Like a child would do it. A child doesn't know formulas, and exponents and compound interest. In 1625, the next year, what was in the bank? There was $24. in the bank, plus the interest he earned on that $24., which at 3.5% happens to be 84¢, so that at the end of the first year he had $24.84. How much did he have at the end of the second year? He started with $24.84, and that $24.84 at 3.5% he had $25.71. At the end of the second year. How much did he have at the end of the third year? He started with $25.71, 3.5% times that is the end of that. And you just keep doing that. You've got to do this 342 times, and you can imagine that you might need help to remember to stop.

Let's assume I want to program this method into the computer, and let me say that as it turns out, in fact, this is the only way to get the computer to solve the problem efficiently. I program the computer, so that it uses some of these expressions but it is costly in time. And if you try to get the computer to do the problem rapidly, this is the methodology you use to program the computer. As we've said, the machine doesn't know the problem. The machine has to be given the information about the problem. Now how much did I have to tell you so that you knew what the problem was? I had to tell you 1624, I had to tell you $24. and 3.5%, I had to remind you that it is 1966, right. Well, we had to count the end of 1966, so in the memory of the machine, I have figuratively represented the memory by these pigeon hole boxes, I have put that information in. I have actually put number one in here, because as you will see in a minute, I happen to need it, and the machine knows nothing. If I need the number one for some purpose later on, I have to tell it the number one. I have identified each of these boxes with a number, an address, because the memory of the machine that we talked about earlier is in fact divided up into these millions of slots. It is divided into little boxes that can hold information like this. The machine, and we identify these boxes by a numeric addressing scheme. My hypothetical machine, assuming that the biggest address I have is 999, has a thousand slots in it. A thousand positions, of which we are using only five. What I have written out here is the program to do this exercise, exactly in that way, and let me just very briefly follow it through. The first thing I tell the machine is the instruction "multiply $24 by 3.5%". Now, I can't say the word multiply to the computer. It doesn't know multiply, it doesn't know what $24. is. All the computer knows is that it has certain capabilities, like add, subtract, multiply divide, compare, etc. Each of these capabilities is a circuit in the machine. That circuit is activated when a certain code comes up. A numerical code in my hypothetical machine if I multiply, is the digit 18. So the machine doesn't know "multiply", it knows 18. 18 means multiply. It only knows these memory locations. So when I want to tell the machine to multiply $24 by 3.5%, I really have to say to the machine, 18 003 by 004, 003 is my $24., and 004 is my interest. That's where I put in my input. This number means something to the machine. Now where is this number? It is in the machine. In fact, it is also in the memory of the machine. Where in the memory of the machine? Let's arbitraily put it in location 900. Now there are two different kinds of memories in that machine. Two different kinds of numbers in the memory of that machine. There is this number which is really an instruction, that tells it what to do, multiply $24. by 3.5%. There are other numbers which are the data. The data which represent the problem. I've got to be very careful not to confuse these two numbers. They both look identical to the machine. They are both recorded magnetically in identical fashion. They just happen to mean two different things to me. This means an instruction, and I put it in that location. Now, I also want to be very careful not to confuse the contents of the location with the number inside that location. I don't want to confuse the address four with 3.5%. 3.5% is the number which is in the address four. These are two entirely different notions, and they must not be confused. Now they can easily be confused because for example, if in the next time I do the problem, I want to use 4%, the number four is going to be in the address four, but that is just a coincidence, they are two different quantities. One is the address of the location, and the other is the number that happens to be physically residing in the location.

I say the next instruction is after I've multiplied, I want to add 24 to this - the result of this multiplication, it is of course, the interest. Now I want to add the principle, $24. to that, and the code for add is 16, not "add". And how do I add $24.? Well, 24 is in location three, so I add location three to the result. The result is sitting in a hypothetical register I have identified as 000. The next thing I want to do is take the result, which happens to be $24.84 and store it some place. I want to put it someplace. So I discover that if I want to store it, I have to have an instruction which is neither add, subtract, multiply, divide or compare, but an instruction which is "store". I suddenly discover that I have to do that. That is one of those extra instructions that I need on my machine. And I want to take that instruction and store it someplace so that I can get at that result later when I do the next line in the computation. I could have stored it anyplace. But since I am only interested in really the final answer, and I'm no longer interested in the $24., because that was in the bank as of the first day, I know at the end of the first year I have $24.84, and I want to store it right in that register. And this works just like a home tape recorder. When you write something new in there, it automatically erases what was in there before. So after this step, $24. no longer exists in the memory of the machine, and instead, $24.84 exists, and that is the current answer. It is going to get harder and harder, of course, as you go along. Now, I can walk you through the rest of these instructions that execute that little exercise. I think if you look at them you can see what we are doing. We then want to keep track here of what year I'm at, remember the machine doesn't know when to stop. So how am I going to tell it to stop in 1966? The way I'm going to do it is, every time I do this little step of arithmetic, I'm going to add one to the year so that at the end of the first step, the year will be 1625. At the end of the next step, it will be 1626, I just keep adding a one. That's why I had to put a one in there, because I had to get hold of that one to do that little addition. Now when I add the one, this number gets bigger and bigger, and I want to stop when that number is 1966. How am I going to know that it is 1966? Well, in this step, I tell the machine to compare two numbers. Subtract one from the other. Now when the result is not zero, it means I'm not through. I'm up to 1925 or 1932. I'm not through yet. Then I tell the machine to go back and keep doing this over and over again until it computes the final answer. I want to draw one conclusion. I want you to notice that the instruction has the structure of an English sentence. It is a very important notion. The instruction says in the verb part, what the machine is to do, namely 18, 16, 20, 7 etc. In code it tells it to multiply, add, store, reset, zero test, tells it what to do. The noun part tells it what to do too. It is the object of the sentence. It says add these things. Now the noun part is different from the English nouns. When I say dog, I mean the dog. In computing, when I say a noun like three, I don't mean three, I mean the information that is in location three, which is something else again. It is a different kind of a logic structure. So there is a verb part and a noun part.

Now you can imagine when you write programs in this way, the kind of clerical errors that can occur in writing these numbers. These numbers, of course, when they are fed to a machine, are automatically translated into the binary system. Because inside the machine, everything is binary, and I only wrote in decimal notations so we could talk about it. Now we have the controls reside in places of memory. To start the machine I go up to the console, and I tell it to go to location 900, get the first instruction and do what it says. Now the machine automatically looks for the next instruction, in the next location, knowing that rule, I loaded them in the next location. If the result of this comparison is not zero, namely, if it isn't 1966 yet, instead of stopping, it will go to location 900 for the next instruction. I'm telling it to go to 900, so the machine goes from 900 to 901 to 902, etc., unless told otherwise. It then starts this thing over and over.

Now, in programming, historically this is an intolerable way to program a computer. To tell it what to do. And it occurred to people that a computer is such a powerful instrument that the problems posed by this method of programming are in effect surmountable by the computer's capability. For example, why can't I instead of saying 18 say mult on my punch card? Or in my other physical media. And then tell the computer that every time it sees the letters mult, it is to translate them into the number 18 in the binary, so I won't have to remember that 18 means multiply. You know that's a hard thing to have to remember. It is different on every single machine. Of course, you know, every machine has a different code. Another thing was why should I have to remember that I put $24. in location 3. The real problem is that I have thousands of these. I'd have to keep a map of where I put every single number, so I might give it the right address. Why should I do that? Instead of saying 003, why don't I say dol, for dollars, and then tell the machine every time it sees the letters dol, replace it with the address 003, then I won't have to remember that it is 003 anymore. The computer will do that for me. Now, if I can do that, I could program this symbolically. Instead of saying all these digits, I could say mult, dol, int. Now the machine would say, "What he means is dol means 30, int means 4, substitute those numbers, make them into binary numbers, and that does it, okay. That's better. For me it is convenient."

Now, it turns out that there are other things I want to do. This is an abstract of how I'm going to solve the problem. Before I read a magnetic tape, this is a machine remember. People can make mistakes, they can put the wrong reel of magnetic tape on the machine. I want to make sure it is the right reel of magnetic tape on the machine. I want to make sure it is the right reel of magnetic tape, so the first thing I write on it magnetically, is the code that identifies what reel it is. When I write this program, I want to do something that has nothing to do with Manhattan and the Indians. I want to tell my machine that before it starts to do this problem, I want it to read that first piece of information on that reel of magnetic tape. And it had better say Manhattan Indian problem. Because if it says payroll, I may spoil the whole payroll tape. So I say to the machine, "Before you do the problem, read the beginning of the tape, and if it says Manhattan Indian you can continue. If it doesn't, put on a red light and stop and wait for the operator to come over, then type out on a typewriter you have the wrong tape on the machine." It turns out that there are many needs like this that have nothing to do with any specific problem, but are problems created by the existence of the computer itself. Problems of automating the assembly representation, problems of keeping track of what you need in memory, memory allocation, problems of checking input media, making sure there is paper in the printer before it got printed. Let it just be hitting the platten, and no information will get out. These are problems generated by the computer, and I'd want to write a little program to solve each of these problems. Now what has happened is that these little problems have grown so that they are not only symbolic programs that translate a few letters into a few numbers, but they are programs which actually have another attribute. They are programs which in a very few words are like check tape. I call on the machine to execute a whole bunch of instructions which tells it to check the tape. That isn't just one instruction, you know. That is a big deal. When I say check tape, I expect the machine to read the tape, read the first number in and check it against another number and compare it, do one thing if it is right, do another thing if it is wrong, a lot of instructions. So with a word like check tape, I expect many things to happen.

Now, that set of instructions, I want to use for every problem, not just for the Indian problem. So I want to write that program once for all time and use it all the time. The result of this is that we have computing languages, with compilers. What are compilers? These compilers are programs in the memory of the machine, which do all these administrative things I just talked about. You take a problem like this hypothetical Indian Manhattan problem, and you feed it to the machine in symbolic, not even numeric mode, but in a symbolic mode. You say to the machine, assemble it, put it together for me, translate it into the numbers. Make sure the tapes are checked. Make sure the arithmetic is checked. Make sure I'm using the right printer. Things of this sort. Make sure the tape guide is really hooked to the machine before you start. And it does all that, and what it produces, this compiler is another program, it produces a program that solves the Indian problem. I told it how to solve the Indian problem. That would be two steps. But I've also asked it, by adding steps at the beginning and end, to do a lot more administrative work, and what the computer feeds out to me is a computer program that really does the whole job, that checks the tape, that checks the arithmetic, that does all this in a binary mode. Now it is like a two step dance. Now that I've got that program in my hand, I've got to feed it back to the computer and say to the computer really do it. Then, and only then, will it solve the problem.

So computer usage today has these two overtones. Half the time computers are used not to solve the problems people bought their computers to solve, half the time it is used to assist in programming. To assist in compiling programs to help relieve the programmer of the burden of communicating with the machine. The other half of the time it is really doing the problems people bought it to do. The first half of the task probably didn't exist before the computer. They are computer generated problems.

Now I've taken the same exercise and I've recoded it in the popular computer languages. This is the way the solution to that program looks in COBOL. This is a business oriented language, and every comma, every equal sign, every digit has to be punched onto a card. They are all critical. They all say something to the computer, and the computer takes these, this information, on those punch cards and when it finishes messaging it, it punches out, or writes on magnetic tape usually, a much longer string of binary instructions which in fact allows it to execute them. This does not solve the Indian problem. This only tells the machine what to do to get ready to solve the Indian problem. The output of the computer from the COBOL compiler in fact solves the Indian problem.

There is a mathematically oriented language used broadly throughout industry called FORTAN. This is the same problem solved in FORTRAN. The differences are that there is a heavier line of mathmatical symbolism, like parentheses, plus signs, and things of that sort than in the other case. Otherwise it is more or less the same structure and format. Here is the same solution yet again in another new language, beginning to be used broadly, called PLANIT. Superficially it looks the same, there are some subtle differences.

Last I want to show you something I did. You know today I talked really for the last ten or fifteen minutes about convenience. If you forget about it, you can still program computers in their raw native language, the way some people do. All other things are there for convenience. To make it easier to communicate. And there is a price you must pay for convenience, namely, you must use a great deal of your computer capacity to produce a convenience factor. So the computer when it is doing that for you, is not doing problems for you, in the sense of real problems, that existed before the computer.

One of the convenience factors that people are interested in is not having to go across town or downstairs into a machine room and handing their problems to a machine operator. They want a little terminal in their desk in their office and they want to be able to turn the button on like in a television set and instantly be connected to the computer by way of telephone lines, or some other fashion, in conversation with the computer. They want to tell it that they want it to solve the problem - the Indian problem. I did that and I copied off how that conversation looked. I sat down by the terminal 35 miles from the computer. The terminal looked just like a typewriter, and although I won't redo some of the typing errors, when I hit the button on the computer after I had identified a code number, so that it knew I was a legitimate user, it typed out the black letters. (indicates) As soon as I hit the last letter and hit the carriage return key, it typed out "I'm ready", and the first thing I told it was to set the year equal to 1624. That is how I typed it in, exactly key stroke for key stroke. And so it went, for the next letter, I hit the carriage return key, it said "I'm ready" and I said, "Dollars are 24". Then I hit the carriage return key and this continued until all this happened. Dollars are 24, and this became ready, and then I said, "Add one to the year", so I could keep track of the year, so I could decide when I hit 1966. I said, "Compute the new dollar amount by taking the old dollar amount and multiplying it by 3.5% interest." Then I said, "When you compare the year with 1966, this code year means if it is bigger, stop, and if it is not, continue." And I said, "When I am up to 1966, print out the answer." Here you will see a special code that is peculiar to the system, a tactical code that one memorizes like any other language. Whenever you say print, you automatically think of saying print zero. And then when I told it all that I said, "I told you what I want to do, start, do it." The question is where to start. "Start at 102, start right here," so the machine said, "Okay, I'll start", and it did. After a few seconds, it printed out the answer in this form. This E means that the decimal point is not where it is, it is in fact seven places to the right. This is just another nomenclature thing, so that the answer seems to be $3,088,000. It did that and it stopped where I told it to stop. It stopped at the end of the problem. Now also did one other thing. From time to time, if I waited too long between sentences in this dialogue with the computer, it would occasionally stop, and I have the actual printing with me and you can see it and you can see all the spelling errors. It would stop and reject and tell me that I took too much time because this particular computer is programmed so that if you take more than 30 seconds of think time between lines, it doesn't know whether you are thinking or if you have walked away. If you walk away, then it is not going to waste time paying attention to you, so it tells you that, and you have to desist from thinking or it will go away.

Now, I ask one other thing. What if I want to compute 4% or 4.5%, or use a different number other than 24? So I said to the machine, "Now you have done my problem and told me the answer. I want to make a change, I want to make a change in particular instruction 105. I want to change 3.5% to 5%", and that is how I indicated this change to it. And I know want to know what the new answer is, and I say, "execute the alteration", that is the code word, "alter it". It now starts back at 102. "Do the problem again, using this new number." Which of course proceeded to do. It printed out the answer, and you can see that the answer is fantastically logical. The decimal place is nine places to the right. That means the answer is now $423,000,000. just by raising the interest rate a point and a half. Impressive, I think. Just out of curiosity, I did another thing. When I hit the start button, I also hit the stop button. You can stop the machine whenever you want to of course. When you hit the stop button, if you are fast enough, you will hit it before it finished the problem. Then you can ask the machine by this code word dump, to tell you where it is when you stopped it. So I hit the stop button, and in that instant it stopped in the year 1944. It had already computed up to 1944, and it told me how much money was in the bank at the end of 1944. And of course if I hit the start button again, it would take off and continue. So this is a very modern way of communicating with machines, a very popular way, and obviously has very great pertinence to computer systems instruction because it is a terminal oriented thing. Now I want to make a point here that I think is pertinent. Although there was no more purpose here than instruction, this program I have used here was not written for instructional purposes. You can see that because you are in a conversational mode with the computer, because you are taking pains to program the computer to accept only proper instructions, to it, you can't tell it to do something it can't do. There is inherent in the thing an instructional overtone, because whenever I tell it to do something wrong, I misspell a word, if I wait too long, it tells me that, and as I use the thing I become a little more proficient. I learn because of the "error dialogue" that keeps coming to me. So computer usage inherently has instructional overtones, whether it is terminal or whether it is in a central computer. A businessman thinks he knows how to compute his inventory. He has been doing it that way for twenty years, and his father did it that way and that is the way to do it. When he tells the computer how to do it, the computer occasionally prints out something ridiculous like, "If I keep doing what you tell me, I will have the whole building full of coal." He learns that what he thought was a well thought-out technique is not. That in fact his procedure has a logical flaw in it. It will point that up. Businessmen have learned that one of the great advantages of the use of the computer in the standard fashion is the discipline it imposes on business procedures. And that is a learning process.

Dr. Lewis: "Would you say a word about the dimensions of the simulation problem? The simulation, the use of the computer."

"In one sense everything you do in a computer is simulation. In a broader sense, anything you do in an analog computer or in a digital computer is a simulation of the real problem. Even when I am calculating a payroll, I am asking the machine to behave as if it is calculating the payroll, and in that sense, it is simulation. I think what you have in mind, the way it is more commonly used is when you have a physical process which could be a measurement on a super highway ramp. It could be people lined up at a theatre ticket booth. It could be a physiological situation in a medical laboratory where you are measuring respiratory rate. These are the things people normally think of. Physical things. Where the computer has been given the mathematical representations of these physical phenomena and by observing the movement of data in the memory of the computer, it is behaving like that physical phenomena. So let's take a simple one like the movement of automobiles on a highway or measuring congestion on ramps. The computer, in fact, has been given all the mathematical relationships of frequency of cars entering a highway, speed of cars, slowdown rate, and what have you, and all the mathematical theorems and cueing theories. What the computer then does is calculate at each instance. It says now a minute has passed, in that minute each of the cars on the highway has moved ahead at a certain distance or slowed down a certain amount, and at the end of that minute, the following number of cars are queued up at this exit ramp, and so many cars have had to go bumper to bumper here. If you want, it turns out a picture of what has happened in that minute. Two seconds later it tells you what happens at the end of the next minute. Now you can tune this as much as you want. The machine is so fast that you can simulate not just what happens at the end of every minute, but what happens every ten seconds, and it can do that in a millionth of a second. So, in a minute, it has simulated a month's behavior in the finest kind of time measure that you specify. And it can print that out pictorially,or graphically, or numerically, and you have a picture of the flow of traffic on that highway. On and off, slowing down at night, picking up on weekends, in a very few minutes, and you can analyze whether you need a bigger ramp or a smaller ramp. You can say to the machine, "assume that the ramp is twice as long, what happens now?" and you get a whole new set of answers. And this is the simulation process. Very, very powerful methodology, that came into being with the computer because you can't do that by hand, it is just too tedious.

Question: "Could you extend talking about simulation to speak about things Simon is doing?"

"This is a very common simulation. One of the things, one of the problems about the real world is that there are things we don't know, and there are some things we know very explicitly. I speak now as a mathematician when I say that, we have valid mathematical representations. They are known as abstractions. But they are valid. You know, if I drop a ball from here down, I can tell you the equation that will predict how long it will take for it to fall, and that equation is accurate enough. It is a very good mathematical representation of the laws of nature. And there are many things that yield to that kind of mathematical representation. Analytic representation. There are some phenomena that do not, such as human behavior.

Let me go back to my inventory problem. I have my bin of hubcaps. And now I want to abstract. I know how to say that mathematically, but there is one thing I don't know. I don't know how to mathematically represent the flow of requests by the consumer for hubcaps. Now what do I know? I don't know how to psychologically analyze the consumer to know when he is going to want to buy new hubcaps. I don't know what the dynamics of buying hubcaps are. All I know is that over the last year, on the first day six people buy hubcaps and the next day seven, then one, then two, then three, then four, then five, then seven, then two, then one, then none, then two, that is what I know. I know that I have a discipline called statistics that can give me all kinds of numbers to tell me the meaning of this distribution, it can tell me the variance from this day, it can give me seasons, it can give me seasonal bias in the same way. It can tell me there is a bias related to bad weather because cars have accidents and then people buy more hubcaps. There can be a bias to the announcement of new cars. There can be many biases. Now, I can do all that, but those are all microscopic measures, mathematical measures of this phenomenon, microscopically, I don't understand. I don't know how to predict that on that day, five people are going to buy hubcaps. I don't know how to do that. That is a microscopic thing. I know how to say that thirty per cent of the people who smoke die of lung cancer, but I don't know how to say whether an individual is goint to die of lung cancer. That is my problem. But in the computer, when I'm simulating, the dynamic withdrawal of hubcaps from inventory, to do that simulation, in view of what I have just said, at some instant in the computer's life, I can tell it how many hubcaps to withdraw today. Today is Monday, how many hubcaps are going to be ordered. I can't give it a statistic. If I gave it the mean, if I said the average of all these numbers is four hubcaps a day, so every day assume four hubcaps will leave the inventory, that is very artificial. It is obvious that's not true. There is only one instance in fact, where four hubcaps were drawn from the inventory. It is a very uncommon thing for four hubcaps to be withdrawn from inventory. It just happens to be the statistical mean. I want the computer, when it is simulating each day's withdrawal of hubcaps, is to in fact, simulate this kind of behavior. I obviously want it, at the end of a month's simulation, which may take a minute, to be able to demonstrate to me that the average withdrawal was four per day, but I don't want to use four every day. That's unrealistic. So how do I do it? Well, to use a technique called Monte Carlo technique, you in fact say to the computer, this is the distribution of withdrawal. And you can represent that curve analytically. You know, by an expression, an algebraic expression. And you say to the computer, figuritively throw a data at that curve, throw a data. Now it does that mathematically by generating a random number. This is scaled so this is zero and that is one, and it picks a number someplace between zero and one, like point six or point seven or what ever. And it does that randomly, and you can be assured of that. Then, having thrown the dart at whatever the withdrawal number is, (the mean here is supposed to be four) it looks at when I throw the dart, it looks to see where it landed. Suppose we start by generating around the number, it looks to see where it landed on this curve, and in that instant that it landed at the point seven, it says to itself in its program, assume seven have been withdrawn. And then it generates another random number, which maybe will drop over here, and that says one has been withdrawn. Now I take another random number which may actually hit the four, so assume four have been withdrawn. What can you prove mathematically? Let me say what you can't prove mathematically. What you can't prove mathematically is that if I let the machine do this, one or two or three times, it is meaningless, because it will just be a distortion of life. But I can prove mathematically that if I let the machine do this dart throwing often enough, and that means millions of times, that in fact, the average of all these events, because this curve is drawn the way I've drawn it, will in fact be four, even though I may never get an instant that will be four. And I can prove that, it is a physical truth. So when I know that, I can then simulate inside my machine, this real life microscopic behavior. Therefore, when I do this problem twice, not one factor changed. The computer is not changed. I have just finished doing it and it printed out the answer. Now I want to do it again. I do the same problem again, and I start the machine in the middle, it will roll up like it did before. Every time it does the problem it looks different because this process of generating numbers microscopically is different every time. In the microscopic sense, the machine is doing a different problem each time. you ask it to do it. Microscopically I am never assured mathematically that it is correct method strategy because of the statistical phenomena. As a result, when you do the same problem twice in the simulation modes, you often get slightly different answers. One time the answer will be that you will have to order new hubcaps once a month, and you have to order 25,000. The next time you run it, it may say you have to order once a month at only 24,800. The next time you run it, it will say you have to order once a month and you have to order 25,200. Or you have to order every 28 days, you know, not once a month. There will be minor changes because no one ever lets the problem run long enough to stabilize it to a point where you wash out those minor differences. Now where it is very critical you do run it long enough. And there are measures to determine that you have already run it long enough so that if you run it longer than you know, the answer in fact won't change. Now this process appears in almost every modern simulation. The Monte Carlo process. Because it is a much more realistic representation of life than a pure mathematical model. It appears even in the simulation of physical processes like petroleum distillation. It suggests, as physicists and people read, that there are some phenomena in life which are in fact random in nature. There are certain physical phenomena which are random. So you can't have an explicit expression for it because, by definition you can't. It is a random phenomena. And so you have to represent it in this way. Of course, for example, the motion of particles in a free environment, the motion of particles in a bomb explosion, say a hydrogen bomb explosion. The thing that you probably know as brownian motion in a glass of water. That is a random phenomena in nature. I mean that is naturally random, and you represent those in computers by this technique.

Carroll Newsome, Vice President for Education of the Radio Corporation of America, has offered here a resounding challenge to education. What does it avail to conquer time and space if it does not know its own purposes and goals? Dr. Newsome's paper carefully delineates the style of operation and the philosophy of one of the giants abroad in the land of the new education. Despite this, there is time for him to consider the needs of the child, the professional, and the economy. He describes several technological and methodological advances of industry and the problems they encounter. Yet his message remains that the burden of direction and responsibility belong to education and society.

Dr. Carroll Newsome

I was very much interested in hearing the tail end of the previous presentation because Dr. Martin may or may not know, I had a little bit to do with starting this thing originally. I was Vice President of the Edison Foundation which sponsored some of the early activities in this area, and I've been quite gratified to see the progress that has been made. I'm not sure, in spite of what Dr. Margolin has said, that the top man is necessarily the man you want in this kind of thing. My particular responsibility happens to extend over 7 major areas and 3 minor areas; in fact, most of my time goes to the field of publishing. I think as some of you analyze this you will understand that perhaps that's where the time should go. When you're done with analyzing the program which is presented to the student, there are lots of opportunities here, I think, for considerable improvement.

I'm reminded, in light of the question which was asked a little while ago, of Professor Klein, the leading German mathematician educator around the turn of the century, who wrote in his book Elementary Mathematics from the Advanced Standpoint, that whenever you are working up a program in mathematics you have to realize that many times the pedagogical does not have too much resemblance to the logical. The way the students need to learn may seem illogical to the mature mathematician. I think we have begun to learn something of that. This was a hard lesson we had to learn in the early days of ESI; in fact, I think we still have some lessons to learn in this connection.

I have in front of me some notes that I jotted down on the plane so that I wouldn't run all over the countryside today. I might say as I start, you have asked me to talk particularly about the computer and some things that we're doing with that, even though I happen to be a personal friend of John Van Neumann, and talked many times with him in the early days of the development of the computer, I no longer profess to be a computer specialist. I have let the other people take it over and it's become an extremely complex area, such that a person in my particular position cannot hope to follow the computer developments in the detail that would be nice if you could do it.

I notice as I read the literature that is put out in connection with your activities that you hope to develop some model approaches to the educational field. It seems to me you're approaching your task in an extremely praisworthy fashion. I might just throw out a preliminary comment that I feel personally that we are embarking upon a major revolution in the educational process, a type of a revolution that actually got started as some of you know back in the 30's but without federal support and so it didn't get very far. Now it seems to be taking hold, first we have technology making a major contribution, and psychology of course has done a lot, so I'm hoping as you people get into your problem that you will be able to point the way in a field where there's a tremendous amount of ferment and a lot of crystallization seems to be desirable.

Some of our people who work on computer applications are very close to me in this work. We have frequent sessions, we argue, we debate; I find at times I do not agree with them; at times they do not agree with me, but I have to present this to you from my vantage point and let me first then look at the hardware end of this thing.

You people of course are informed about the controlling unit of these systems with which we're concerned, which is a digital computer; it's been described as an information processor. I like to think the analogy can be found perhaps a little better in the field of behavioral psychology where you get a distinct reaction to a specific stimulus, you program the thing in advance so that it reacts in a very specific way for each particular stimulation that you feed into it, which of course puts a great burden on the programmer. This is immediately important. Now when I come to this mechanism, I think it's only fair to say that its capacity for storage will increase, the speed - time in which it reacts is going to increase quite decidedly, the cost of the computer is going to come down, some of the things now in the works are bound to have a great impact upon the economics of this field. As you look ahead in trying to analyze the role of the computer in the educational process, I think it's only fair to say that the cost - the economics of the thing - will change drastically in the next few years. One thing that I'm sure you all realize, it's become a fundamental part of our thinking, is the fact that schools, colleges, universities, going into this field will not go in with the thought that the computer is going to be used solely for the instructional process. Rather it has many many other uses; I'm impressed by the number of school systems now coming into talk about computers to help them with their record keeping, their guidance problems, their basic management problems, and so on. The computer will not be used only in the instructional process, but we find a growing tendency to superimpose the instructional process upon another usage, which of course again changes the economics of the thing.

May I comment that we've been inclined to use the term CBI, computer based instruction, instead of CAI. The computer will have a more general relationship to education than just direct instruction. One of the problems with which we have been very much concerned has to do with the various input and output devices, in otherwords the interface between the student and the system. How is information fed into this and then how is information returned to him? I would like to predict that in the next decade the greatest progress perhaps in the hardware area will take place in these particular areas. A company like the one which I represent has major research projects that have to do with character identification, in fact considerable progress has been made in this area, voice identification so that you can talk right in and communicate directly with the machine. You will have return devices of the same type, you have so-called light pencils, and many different types of displays. I might say, this is an easy thing for a company like the Radio Corporation to concentrate on because knowledge about these things becomes fundamental to many other parts of the company's operation. We don't usually talk about the amount of money that we put into this interface type of equipment, but I think that you might be interested in knowing that our annual expenditures, just on this kind of thing, these input and output devices, is up in 8 figures. This we believe to be quite fundamental. We have to be able to convey information to the student at the level of sophistication that he can take it and use it. The input operation has to satisfy the same requirements.

As you look then at the various computer systems I think you will find that at the present time these are fairly crude with respect to this interface equipment. It is a very tricky process to develop this kind of thing. Many of the things I am talking about, or at least have implied, are available, but they're in the process of perfection. Sometimes I think companies may be too conservative, but there's real hesitation, especially in a teaching situation, to put out something until it's really ready. I think one thing that we have had to learn as a result of our experience, we've had a certain amount of very interesting experience in trying to teach youngsters with a computer system that we have in operation, is the fact that the mechanism is not thoroughly de-bugged. If it doesn't work perfectly you're in trouble. We've had some bitter experiences already where a youngster finds himself thoroughly demoralized, he loses lots of confidence in the operation, if it doesn't work right; if the image is blurred; if for some reason it isn't doing what it is supposed to do.

Personally, I've been very conscious of the necessity of getting the best of this type of interface equipment. We've put some things out to try and then we've yanked them back because we thought it wasn't good enough yet for students to tinker. Students have a tendency to personalize these things you know. I was very interested in watching a little girl, a while back. After she'd been corrected about three times in a row, she said - "Well, I'm trying the best I can; don't you know it?" And this is a very interesting thing - how a mechanical device becomes personalized after a while. This of course becomes a real challenge to the people who are producing this equipment. You have to realize this - that you can be less than helpful if you don't come up with hardware and the software that has been thoroughly debugged and works very well.

But I wanted to throw this in because I think generally as you get round the country and see what is going on, in the use of CBI (or CAI) you'll have a certain amount of dissatisfaction as I have in regard to the interface equipment. Much needs to be done; it's an area in which we're doing a great deal and I'm sure the same thing is true of other companies. As I say this is not too much to ask because we need this same kind of equipment for other applications of the computer, beyond what you do in the instructional process.

Now coming to the software. I heard the previous speaker say quite correctly that we've got to give proper attention to the software. I think the teaching machines, the elementary teaching machines, that were out here a few years ago failed partly at least because of poorly created software and inadequate amounts of software. So much attention has to go into software that we feed into these mechanisms. You may have to experience it to really realize what a tedious time-consuming and expensive process it is to develop this software. You can spend an awful lot of money before you know it, and occupy many many people in the development of this software if you're going to do the kind of a job that you want. We decided very early and we've been playing with it now for quite some time, that to get the proper kind of software is beyond the capability of one particular company. After all, knowledge is very big and you've got to have diversities of approaches. Some of you may have noticed in the press a week or so ago that Harcourt-Brace announced that they were developing software for our system. I don't feel free to announce the fact that there are four others similarly engaged. They will have to make their own announcements. There's no contractual arrangement or anything of this sort. It's pretty much the same sort of thing as the Decca people making a record to play on a machine over here developed by someone else. I like to think this is a very important development, because the more the different groups we can get in experimenting on different kinds of software, it's highly desirable. And the approaches of these groups will vary somewhat; they'll be trying different subject matter areas. But I think it's quite important that we now have many people working in the software area, creating substantial budgets to work on this. I think this is a very good omen.

I've been curious all along as I look at this software area. In fact I used to debate these things with Omar Moore a good many years ago. I think as you analyze the use of the computer in the instructional process, knowing something of the limitations and so on, I have become convinced there is a kind of a sophisticated level on which some things can be done. I like to think that I can see approaches that actually come to grips with the inductive process for example, and so on. But this is not easy. First, you're all aware of the use of the computer in a great variety of research process. But I'm sure there's kind of an esoteric area up here that we do not as yet understand. However we have another area of activity in which we're working now, you might call it kind of a non-sophisticated area, and I like to explain it this way - that we now are in the process of programming these computers in areas of knowledge where we have complete systems. Omar Moore used that same expression. I'm sure you know what I mean, and this is a mathematical expression, and roughly speaking what we mean is that we're working in areas of knowledge where most proper questions can be answered in terms of the accepted principles of that branch of knowledge. Some of you may be familiar with the theorems of Bertiolli and others who actually demonstrated that a complete system is not possible. This of course gets again up into this esoteric area which makes the whole field quite exciting. In fact I think that we will find more and more that some of the things I'm talking about here become major activities in the field of logic and foundations of mathematics, because here are some very interesting ways in which these things can be used.

For example, we have been doing a lot of work in programming computers to teach skills in arithmetic. Here, so far as we know, Whitehead and Russell professed some years ago to think that they had demonstrated that you had a complete system, a consistent system, in other words the accepted principles of arithmetic are adequate to answer all proper questions. We don't debate whether 2 + 3 is 6 or 8 or something else. Here then you have a well-defined area of knowledge where we can work with considerable satisfaction. Consequently, some of us, some 3 or 4 years ago decided that the areas in which we would first tackle this matter of programming the computer were in such areas as this, where you had complete systems. Plain geometry, of course, would be another. You can think of many others, but arithmetic is a very simple case. And of course you can go on in other areas where the principles are well defined, and where we think we have complete systems, to prove this kind of thing is very difficult, but on the basis of the evidence we think we have a start.

At the present time the company which I represent is spending a lot of its time in developing drill and practice materials. These materials obviously then are supplementary to what else the teacher does in the classroom We expect the teacher to take the lead, providing the underlying theory, the explanations, but when it comes to the matter of drill and practice, the youngster appears before his console and he goes through this sort of thing.

I understand you're going out to Palo Alto. Much of what we are doing now, what we discussed three or four years ago, has taken form in what is now going on in the Brentwood school. You'll have some very interesting demonstrations of this kind of practice material. We have evidence that this works very well. We have been playing with this now long enough to see results, and test these results against other procedures. One thing, of course, that's interesting in all these computerized developments is the ease with which you can make changes. It's a very interesting thing; it runs into what we're now calling our graphic systems too in which we're editing pages of newspapers and magazines, and the ease which you can make the changes is fantastic. If a particular approach to one of the principles is not giving good results you can rather quickly make necessary adjustments.

At the present time my major efforts are in the field of the elementary, arithmetic and language arts. We expect in our case, that our educational representatives and our psychologists would take the lead in this. I exercise a certain amount of right to debate with them, which I do frequently. I can be fairly cantankerous if necessary in insisting that I don't think something makes sense, but nevertheless, they take the lead and they bring up the proposals for us to debate the approaches that they propose.

We are moving into more advanced activities. Dr. Duncan Hansen, of Florida State University is a man in whom I have great confidence. I think if you get a chance to visit with him, it would be very much worth while. He's a very forward thinker in this whole area; I've gotten to be very high on Professor Hansen because I feel that he's got a philosophical approach to this thing that is very very sound and profound. You'll have to talk to him at length sometimes to really understand the depth of his perception of what is going on here. He is not a superficial man at all; the kind of fellow I'd like to think will be determining some directions.

So as we move ahead in some of these areas I'm sure you would agree with me that one of the best ways of teaching any subject is what we might describe as the Socratic method, instead of sitting down and telling a person, this is what you do, you ask him questions - why did you do thus and so? When he replies, you raise another question, rarely inserting a positive comment; in fact, a couple of years ago I went through several derivations in the calculus this way. I happened to have played with this many years ago as a teacher and it's the kind of thing that now we're beginning to introduce. You can use this in fairly sophisticated types of derivation and analysis of problems. Just the question and answer method you know. It isn't of course the usual lecture approach, but that obviously is passé as you go into this kind of thing. It's within the context of what's possible and what's desirable in this area. We're having a lot of fun now debating where this can be used, and where properly it should be used, in more sophisticated work. In fact some of our men are now working on what they call the tutorial, which is essentially what I'm calling it. Patrick Suppes out at Stanford may tell you a little bit if you ask him about things that he's doing and what he describes as the tutorial.

Another area in which we've been working with a couple of other agencies was cued a bit by what is going on in the field of medicine. Traditionally our tests have given us some numbers that we then have tried to interpret; as one of the leading testers said the other day: "Really, all that these things have done is to give us symptoms. They really haven't given us any diagnosis." We are now moving into the realm where we can get diagnosis. What are the basic troubles of kids? The difficulty appears over here and over here, and over here. They may seem to be disconnected but there's a pattern that runs through that can be detected. I point this out as another direction which we now have considerable interest. We call it the diagnostic use in which we propose to do something with people who have learning problems and who are not doing too well. We hear much discussion of Negro education. How can we move into the diagnosis of such basic difficulties and the need for this diagnosis?

I don't mean to say as I point out some of these directions that this represents everything in the future. It's become kind of an axiom in our operation - that any of these things that I'm talking about merely become a part of the educational program. We do not see, as of the moment, a computer or any of these other devices taking over the entire instructional program, except possibly in business and industry where you have restrictions on the availability of teachers and you have to do the best you can. But in the school itself, in the formal schooling process, we're looking at all of this as simply being one component of the educational process. I think I may be a little bit responsible for this because of a basic concern that I've had for years, tied up a bit with what I said a while ago about dealing with complete systems of knowledge.

I've been concerned for much of my adult life with procedures that maintain the status quo that we have sort of built in our educational system. We are determined to teach kids the principles which we have set which are orthodox. We must more and more encourage the unorthodox. I happen to be a student of Mr. Einstein a very curious man. I don't want to start giving you a dissertation about Mr. Einstein; but I happen to believe in the case of Mr. Einstein, who was untutored. I remember Miller touring the country back in the 20's saying how could physicists accept the kind of childish thing obviously written by a man who knew no physics. Well this is correct. And as you look into his background I'm sure this is right - he knew no physics. I used to talk to him at length, he knew no mathematics either. He, but he came up with these principles because he began to look at these phenomena untrammeled by the accepted, and came up with new doctrines. I believe this sincerely. We had a very interesting experience over at ESI. One youngster who was regarded as a moron, a Negro lad incidentally, who would take hold of certain pieces of apparatus where you had unequal levels of water would adjust them. When he was asked to explain: "How did you know how to do that?" "Very simply, see so and so and so and so." The physicists smiled because they said he doesn't have the right explanation, even though he got the right answer. Under further reflection they decided his explanation was better than the accepted one, and it was then put back into the material.

We have to watch this, especially in some of the areas that are not as well developed. We want thinking that isn't absolutely orthodox. We can do a lot in teaching people what is accepted, and be sure they know what is accepted, what is orthodox. We get the replies that would indicate that. But I see no substitute as we go ahead to seeking different approaches. In fact I happen to be a personal advocate of many seminars of 10 or 12 youngsters, where you get an interplay of minds, perhaps even with a student moderator. Things come up that are not found in the testbooks, interesting ideas that need to be explored.

Well, I'm simply saying that we now are working on the assumption, other people may disagree, that anything we're doing in these areas can only be a component of the whole instructional thing. We can do an excellent job as we're doing now in arithmetic. Our success in teaching the multiplication table is fantastic. These kids know it. In fact when they get through with the kind of an experience that they go through here they know the multiplication table and they learn it in a fraction of the time - no question about it - the evidence is all there. A lot of these areas - there's very little excuse in the future for poor spellers. A lot of this is just a matter of drill. Irregular words do not seem to obey the conventions, you memorize them. The success in teaching youngsters to do these kinds of things is terrific. So wherever you meet the need for drill within established conventions you can do an awful lot. If you move on up into fairly sophisticated derivations you can do well. I have been working with a fundamental theorem of integral calculus. You can teach this this way and go through it step by step. You never explain a thing - just asking questions: they reply - like: "Why did you do this? Didn't you know this?" and so on back and forth. Then they go through and make their own derivations.

I'm sure you all agree that ultimately the environment, the learning environment in which we place these kids, will contain a lot of things. We will see coming together a great variety of audio-visual approaches, many different things, in which the computers, aiming at CBI as merely a part, I think this is another thing that has to be anticipated as you look ahead. Instead of thinking of it as an entity in itself, how does this fit in over here and over here and over here. I'm concerned with how it plays a role in the area of instructional television. I think I begin to see more ways in which this will work. So we will be seeing coming together in the future a lot of these things. I simply ask you then in your deliberations not to think of this in any sense of the word as a kind of separate unit. Instead ask how does it fit in with many many other things that are going on. I'm very much concerned with the teaching of language, playing with it in many different ways. Yesterday we made available to the public these taped cartridges that you can take home and simply stick in your set, if you have one of these things, and receive drill on language. I'd way we're only 3 years away from a general instrument in the classroom that you can program for the use of cartridges to have the audio displays you want. Visual displays are in, blackboards of course are out. Visuals will come over a big display and the ease with which many of these things are being done right now, or can be done is amazing. When you take a little cartridge like this and you put it into an instrument; just push it in and it starts; it goes for an hour and twenty minutes. And you can select out of it anything you want. By the way this becomes a part of your computer based instruction. The audio forms of the device will be available very rapidly, just because we have it under control. Some of us have had considerable success in controlling the mechanism that makes this audio display visible.

Well, I'm going to stop here. What I've said may appear to be more philosophy than anything else, but I thought you would be interested in seeing this field as I see it. I'm not a computer expert, but one who inflicts myself upon those who say they are. I may have indicated a little of the direction and the present status of the art as I am inclined to see it.

I might say this, I hope you don't mind. As industry gets into this, it's been traditional I think for there to be a schism between industry and education. I know this was true back in the 30's. I feel now that the orientation of industry is very strongly toward education. We have regular seminars at Princeton on the learning process. Of course, we have a lot of behavioral psychologists there and so on, and we get a lot ot this kind of thing. And in fact we have been a little critical of educators. One of the fellows who was in today said: "I wish we could get these educators to think more in terms of fundamentals rather than in terms of gadgets." I have recently had representatives, a team, from a well-known teaching institution in a while back. They said: "Would you work with us to develop a model teaching environment?" I said I'd be glad to and talked to them a little bit. I said: "Are you prepared to tell me what you're going to try to accomplish? What is it you want to do here?" Their answer was: "No - we thought you'd have something to supply."

I think few people know how advanced technology is at the present time. We can give you almost anything you want. Now it may not be as perfected as we might want it; but it's pretty hard for you to name anything, now this is amazing maybe, that we can't do or couldn't give you after another year of so of perfecting it. But the challenge right now is an educational challenge. What are you trying to do? What are you going to do with the kids when you get them in there? What kind of environment do you want for them? I had a president come in yesterday from an institution in the Southwest asking: "Can you come down and build us a modern institution?" "Well, what are you going to do with the kids down there?" Answer: "Well, I don't know, you tell us. !!"

As you get into this area I'd like to emphasize my personal belief, that industry is pretty conscious of these things. Frank Keppel and I spent a lot of time a few weeks ago talking about it. We're trying to get down to brass tacks; we've got to see what is fundamental in this thing before we get too much involved with gadgets. And so I just throw that out for whatever it's worth, because I think education has a real challenge now.

Much of the development of CAI will depend on the effective interaction of industry, education, government and the ultimate consumer. At least a portion of this cooperation was demonstrated by Mr. Muller's participation in and assistance to our study. His paper states, in direct and lucid fashion, some of the problems faced by industry, and addresses itself as well to industry's need for both restraint and support. In addition it provides a comprehensive view of the state of the art at this date. This frank summary of CAI from the corporate point of view provided a valuable launching pad for the briefing of the panel.

Mr. Leonard Muller

This is a presentation that has been given a couple of times before. It was a presentation by us, to Dr. Hornig and his group at the White House, and later to Commissioner Howe and some of his people. The purpose of it was to give our view of technology in education at the request of those groups. That is the fundamental subject you folks are concerned with.

We call it the Busy Chart, and it was deliberately made busy because in this particular chart we were just trying to convey a fact that you all know far better than I do. It wasn't many years ago that the process of education was reasonably simple in terms of development of curriculum materials. That is to say, there was a time when a man could sit down and from his own mind, or from the mind of one or two people, develop a book which was the fundamental element of a course. He would then find a publisher, publish this book and then, based on the brilliance of the teachers who used it, you had a course. And the point of this chart is merely to say that the thing has become vastly more complex. That today we have a great many more media than just books. We have many different things, such as audio-visual aids, television, language labs and computers. But in the educational area more and more of the educators are beginning to consider the fact that the student body is not a homogeneous group at all, but highly heterogeneous and has to be treated differently. The key point is that there are two particular groups of some importance which have entered this area, for good or for ill, government and industry, and are impinging upon the educator's traditional role.

But there are a number of different methods by which these many different media can be applied. Virtually all the disciplines at all levels of schooling in the framework of this heterogeneous school system and student body are involved, and with the involvement of all of these people, the thing is getting awfully complex. Too complex, perhaps. If these innovations are to be successful there, it's going to be a challenge to the participants here to bring some orchestration, some fruitfulness out of all the things that seem to be impinging on or entering the educational area.

Education today, in fact, is just not the traditional formal education, it is every type of education imaginable, including more and more adult education as time goes on and as the needs of society rise. As a business man I rely heavily on a lot of advice from educators both within and out of our company, and the net of all that we can see putting our heads together is that technology in all forms does enter virtually every discipline imaginable. It isn't just in the hard sciences for example. I am very interested to see that there is an architect in this group, and I gather from this and the other names on the list, that the total organization of the educational system, from the actual construction of the agency to the way it is managed and organized would undoubtedly be radically affected by the introduction of thise innovations. Not only technology, but also the many other teaching innovations that are coming will be considered. By the way, when I interrupt myself here, to say that I apologize because at times I am going to speak to some of you who know a great deal more about certain subjects, I know many of you know a lot about CAI, and some of you don't. So based on our lack of individualized presentation, Forgive me.

You are interested in where we will be in 1980. Clearly, the computer and many other technologies, such as video presentation and so forth, are going to result in a much different educational organization. Instead of a traditional classroom with a fixed number of teachers to draw on resources, there will probably evolve specialists vastly different in role and function from those we have now. Already this is happening, different arrangements are being tried ranging from no teacher and one student, all the way up to the teacher and a very large number of students. There are going to be specialists, and they are going to have to be involved in teamwork. For example, as we get into CAI, I am sure that course preparation will evolve from teams of people. Media specialists who understand the best way to present materials from a visual-audio standpoint, subject matter people who understand what needs to be taught, programming oriented type of people, I don't mean programmers, but people who are capable and interested in program development. Most people are capable but many are not interested in the extreme discipline that is required to construct computer instruction. The impact on the structure of education is going to be profound. To begin with many factors limit mass use. I think it is interesting to note, first of all, if you put one terminal in every classroom in the United States, it's a wild guess (because we don't know right now what the state of the technology will be), it will probably require the combined manufacturing capacity of every computer manufacturer in the United States. And similarly, to change the structure of two million classrooms, or institutions involving countless people is not a simple thing. This is obviously a long evolutionary process, but we do see that it is happening. And finally the point of this chart is merely to re-emphasize that there is no one technology that is the answer.

As an example of the necessary orchestration of media and method, in any given course, in a sample week, on Monday, the use of slides for a lecture might be the case. But the next day perhaps the exposure to technology might be a CAI terminal for some instruction and some testing. But possibly another day a video lecture, and finally, another day perhaps you would use the computer in a simulation to test out what the student has learned, and give him a chance to exercise it, and finally, perhaps a documentary film. So there are a number of different devices. I think that one of the great dangers that all of us in industry have to guard against is getting our particular product and trying to push it as the panacea. We are very sensitive to this in our own particular company and I think that industry can do itself a great service, if it is very careful in recognizing this so that it doesn't put itself in the posture of telling education what is good. Instead it puts itself in the position of presenting an array of things that education can select from, that it can emplpy if it chooses.

If you look at the vast array of media that are available against this structure, this environment of teachers and students, against all the disciplines involved with all the approaches you can take it is impossible to discuss any one particular one in great detail, or any group of them in great detail. Nevertheless we are convinced that the computer has introduced a very pervasive technology. For this reason, I will confine my remarks to it and give you some of the ideas that we think apply to the use of the computer in educational process. We've been exploring what is called computer assisted instruction since about 1957 in our research laboratory. We got out of the laboratory about 1960 and we began to put terminals into a number of universities around the country on an experimental basis, on what we call joint studies with these institutions. Out of that has grown the conviction in our minds that there is something to it. We're not yet sure, but now we admit that there is sufficient evidence there in certain areas. We are absolutely positive in other areas that it merited going in in much greater depth into education to prove this thing out. We are at that stage now. I know that you all are going to Brentwood and other places where you'll see both IBM's and other manufacturers' attempts now to try to get this new concept actually validated under real conditions. We feel that we are now more or less in the Sarnoff's color television syndrome stage with CAI. The problem is that you know you have something in color television, but nobody can afford to advertise because there aren't enough color sets out, so nobody does color programming. Nobody bought the color sets because nobody did color programming. We have the same situation here with CAI, you are not going to be able to provide CAI hardware, which we are interested in doing, unless there is programming for it, i.e., the course material. And of course you are not going to get the course material developed unless somebody has some hardware to do it on. Well, we find ourselves at this impasse, that is why we developed a system on an experimental basis to try to break the ice. I hope other manufacturers will try to do the same.

Now the purpose of this presentation is to say the following: That we have tended to fill in I would say all of us, including this particular group, my own company and universities around the country, have slipped into an aspect of computer assisted instruction that is only one part of the whole picture. I would like to say that anywhere the computer assists in the educational process in the future it will be computer assisted instruction. The purpose of this chart is to say that there are a number of ways that this can come about. The tutorial approach. The Brentwood approach, which we are deeply involved in, the University of Illinois, Florida State University and so on are primarily aimed at the tutorial approach. There are many other approaches to using the computer in education that can have as profound an affect in the long run as what we are now tending to confine CAI to, which is this area. If you will bear with me in the theory that anywhere the computer assists instruction it ought to be called CAI, then I will go on, I really don't care about the terms.

I don't know how many of you know of John Flanagan's work as head of AIR - (American Institute of Research) out in Palo Alto, California: Westinghouse is financing it. He is developing a program for which there are great hopes where the student is never on the computer at all. I understand you are going to Oakleaf. The great problem at Oakleaf in the attempts to individualize instruction is that the actual record keeping problem becomes impossible. If you have any number of students who are going to move at their own pace, particularly if they are going to use different speeds, you get into a counselling-guidance-testing-record keeping and scheduling problem that confounds you. You get into the very problem you get into in terms of calculations required to get someone to the moon. And again this is the place where the computer can do a fantastic job.

This chart is just to point out that the computer is a fantastic problem solver, and we know it. There are 30,000 of them installed in the United States. I know Lou went through the thing with you this morning and I hate to follow him. But we know it can do fantastic things in problem solving. And this fact is a very important element in education. On the other hand, a report put out by a Presidential Advisory Committee on this recently, said that only 5% of the college students have adequate use of the computer, but another 35% need that same amount of access, and another 40% require comparable amount. You are merely talking about problem solving at the college level. This chart tries to show that it isn't just confined to mathematics, physics and chemistry, but also operates in the area of social sciences, in the study of criminal behavior, etc. You can provide a student, for example, with data, which is available, general statistical data, i.e. how many people with income from $5,000 up or have only had a grade school education, or who are married, or any kind of real or constructed data. Given this kind of information and addess to a computer, a teacher can assign problems of rather high difficulty, such as this one. What is the probability that an unmarried college educated male who earns $7,500, Protestant, aged 25, will commit a burglary? New, the point of all this, and I've seen it happen where we've been experimenting with children, it leads students to question, when they can start. They really get excited, and they really do start to probe into areas that otherwise they must either just read out of a book or settle for someone else's opinion.

So, the idea of using the computer just as a problem solver suggests some very interesting possibilities. Let me give you another example. Charlie Miller of MIT has been doing this now for a number of years. He assumes that the computer as a problem solver is a powerful tool to be used in his classroom. He teaches civil engineering and, giving the students considerable access to computers, he assigns them problems involving computers. As an example, he is assigning his freshmen level students senior level civil engineering problems. One example that I was given, was the development of one quarter of a cloverleaf of a superhighway. Apparently it is a very complex problem. You get into grading, and spacing curving, and what is called filling and so on. A very complex problem. He assigns it to his freshmen, in the college, one freshmen class, mind you, a problem you ordinarily assign to senior civil engineers, and every member of the class finished it. Some members of the class went on to finish all four sections of the cloverleaf.

Now, suggest the possibility that you may want to teach a student how to solve a simultaneous equation. From that point on, one can argue, and this is up to the educator to decide where you draw the line, whether he ever needs to know how to solve a simultaneous equation again. A computer can solve untold numbers of simultaneous equations and very complex problems for them. You can have a flight of fancy here, and again, I think education's decision. It is not whether it should use this, but how. You must question it, just as you must question of a dictating machine whether it really is necessary to teach a child to write. It is a real question now whether it is really necessary to teach a child to add. Of course, I'm just being facetious here. But there is some relationship. You now have the possibility of bringing a student in to design a bridge, instead of just one element of the girder. He starts at a much higher level and its very exciting.

The area of simulation is very little recognized by laymen. But interestingly enough, we have for a number of years known how. Mathematicians and others have known how to use the digital monitor of a computer as a fantastic simulation device. I personally saw, at the Atomic Energy Laboratory in Livermoore the entire atmospheric envelope of the world simulated on a computer, and then through the use on a television like scope, a cathode ray tube, an instrument similar to those used at the Palo Alto-Brentwood School project.Then by a very complicated simulation method, the photograph was put in motion, in three different colors. The minute it was, they showed the world at a steady state, and they had simulated on the computer all the effects on the earth's atmospheric envelope of gravity, cosmic radiation, the differences in temperature of the varying bodies of land and water, the friction of the earth, etc., etc. It started in a steady state, you could see the Western Hemisphere which is what they chose to show, and suddenly they had shown by these three different photographic effects, the isobars and pressure levels, the temperatures, and then they showed weather itself, the rain, and so on. Slowly, this thing was put into motion, and bit by bit, the Bermuda Low began to appear, and the Atlantic Low, which apparently is a standard of weather phenomena, and another low - the Vancouver, somehow which is usually generally clear. You could see weather moving across the United States, rain began to form, and so on. A complete, if not perfect, but probably rather good simulation of one of the most complex phenomena possible. Now, the point of all this, and let me just skip ahead and show you a similar type of thing. This is a printout, from a computer, on a printer, of a simulation of a fluid dynamic situation. Where a solid column of water is set in motion, is released, and a wave begins to form. Now the possibility here is to expose students, in a simulated environment, to vastly more complex things than we could ever afford to expose them to. You just can't afford to put a Taylor Model Basin in every school in the United States, or inside a chemistry laboratory, or what have you. But, every day, right now in the United States, at North American Aviation, if you go to Taylor Model Basin, if you go to any of our research centers, you will find untold programs, already written simulating various physical phenomena. Flow dynamics, thermo dynamics and so on. And here again, my point is to say that not only can this be possible a very powerful tool, but that the material is already there. All you need to do is somehow back it down, so that our students who are going into that environment learn to use it. Instead he has to wait to become an adult to learn to use it.

Now the purpose of this charts (indicates) is only to show that a computer can be used to simulate some of the simple laboratory type experiments in a physics laboratory. In this particular case, this is just sort of a terminal where you have a way of displaying via slides, a cathode ray tube and a way to communicate to the typewriter, a traditional inclined plane experiment which you would assign a student in physics. Where he would have to go in and make the measurements, vary the angle of the inclined plane, and vary the tension on a body on the plane, take certain measurements, go back and plot a graph. This is part of understanding certain phenomena. You can simulate all of this on a computer, as is shown here.

If he doesn't know laboratory technique, you can teach him laboratory technique in one or two laboratory experiments. It is questionable as to whether you want to teach everybody laboratory technique or not. Again, that has to be left up to the educator. The advantage here, of course, is that you can, in this particular instance make many, many more measurements and having the computer right there, probably assign a more complex problem which he might solve on the computer. We have in one of our laboratories, literally simulated in this way a complete quantative analysis experiment in chemistry. Very difficult to do, a very costly program to develop. A group of chemists, collaborating with us went through every reasonable path that a student would go through in analyzing an unknown in qualitative analysis in chemistry. We photographed this with color slides, step by step. They put that in a machine that was designed to show color slikes and then set up a computer program, that allowed the students to sit down and sign in. The first slide comes on and he is shown a picture of a test tube on a laboratory stand. The student starts his test, and he types into his typewriter "litmus paper", and "litmus test", and the next slide then comes and then shows the litmus paper sitting by the tube, and its red. He now knows that its either acid or base. He then says, "a centrifuge," and types it in, and a picture comes on and it's centrifuged. He moves right through, and if he's wrong, he'll be shown pictures just as if he were in a laboratory and doing things wrong. And in the end, if he is wrong, he'll be told he's wrong otherwise he'll know he's right. You find here, ability to move through many more experiments than you normally can when you spend most of your time in the laboratory. The possibility of actually lower costs exists as well as improving and expediting education. By the way, I'm not suggesting that here today. We have such an element done. It shows that it can be done, and this particular one the University of Texas intends to extrapolate from. They hope to develop a course around it. They are starting on it this year.

Of problem solving, I have suggested that it is only a question of developing it, working it into the curriculum materials and making it part of the classroom experience. And the same thing is true of simulation. Simulation has already been proven in business schools, many business schools are now using computers to simulate business experiences. They actually program a model business and students can play the part. One student plays the part of the vice president of sales, another of production, another is the president of the company and so on. They make decisions and put them into the computer, the computer then operates through this simulated model of a business and comes back to them with a report on what really would have happened in that particular business if they had taken the actions they did. Harvard Business School uses this all the time. It is now programming what we call "real time" use of the computer for a business game. By that I mean instead of just all of us playing eht game here by writing on pieces of paper and having some girl punch up what we want to do on cards and put it into the computer, each of us has a terminal. Joe would be Vice President in charge of research, Glenn would be Vice President in charge of sales, Lou would be the production manager and I might be the manufacturing manager and so on. As each of us starts to play with the computer and make decisions, it reads back situations. Glenn's sales go up, all of a sudden a production problem will appear on his terminal as a problem he would esperience in normal business and he must respond with certain actions. Either Glenn or Joe may be able to solve it. You actually get a situation where students are virtually operating in a real time environment as they will later on but at a greater rate of speed. You can go through ten years in a business company's life, for example, in a matter of a few hours, or a day. This has already been demonstrated in business schools. The university of California at Irvine how has an economics game, written by an economics professor there, where as part of his normal course in economics, he has the students go over and play a game on the computer terminal, where they are confronted with problems of supply and demand, as simulated, it has to do with wheat commodities, and they are able to practice what they can learn and see the affects of decisions they are making in economics. So we believe that simulation has the promise of exposing students, in the very complex society of today, to much more complex environments than is usually possible in an educational process.

The tutorial dialogue is the feature that has had the most publicity. I would say that the greatest amount of research has been put into it by companies and by educational institutions and by the government. And for a good reason - it does have great promise. The purpose of this chart is again to give those of you who may not be acquainted with CAI an experience in a very simple way. This is terribly over-simplified so that you can understand what we are talking about in the tutorial dialogue mode of CAI. I know Lou has gone over this morning the ability of a computer to make point by point decisions, including what we call branching. This allows you to vary both stimulus and appropriate response and just what capability can be built in a tutorial mode of CAI. The student may be prosented with some materials for review, and then move on to a diagnostic test where the student who hasn't been on the terminal for a week but whose records have been kept in storage is presented with the course where he left off. He may be given a little test to see how well be has retained what he has learned and the computer can then, on the basis of the programming, determine whether the student should continue on or perhaps, maybe not go on. Perhaps he should go off the terminal and go back and see the teacher because he is having serious problems. But let's presume the student can go on. On the basis of this test and on the experiences that the student had in the past, the computer may decide that the student should take some remedial work before he goes on. The computer has the capability, where it has been properly programmed, to branch the student to some remedial work and present him with maybe some dialogue, a series of questions, maybe a reference to a book he can go to, and then, based on his performance, he can be carried onto the next level.

The next chart provides an example of that to show the more esoteric and sophisticated levels of CAI, where you actually use audio, prerecorded tapes that are under computer control, a cathode ray tube that can project numbers, letters and symbols directly from a computer, slides that can project from a store of say one thousand, two thousand pre-made 35mm. slides, and ultimately perhaps movies and a pen, called a light pen. This is an electronic pen that allows you to touch something like a cathode ray tube or a television tube. Properly constructed and programmed, it provides a way to cummunicate with a computer.

Now in this particular example here with a student now - he has signed on, he has passed his test, except that the computer, based on the way it was programmed has determined that he needs to have a little bit more review about Roman history before he goes on. So he hears over his earphones the following question. Can all of you see that? Now all he needs to do with the light pen, here are the various answers, is to point to the appropriate answer, and the computer will know whether he has pointed to the right or wrong answer. Now, again for those of you who haven't seen that, I know you'll see that next Monday or Tuesday, in California when you go to Brentwood. I don't know if you'll be seeing other light pens around, but there are other light pens. And if the correct answer is given, then the computer can select from the prerecorded tape created by the teacher or the course author, and can reinforce the student with a cheery "correct." If he is wrong, it can tell him he's wrong and maybe again make a decision at this point. "It's the third time he's missed a question here, maybe we had better branch him right off the computer and send him right back to the teacher." Or it can even alert the teacher on her own console that this student is having difficulty. So when people get threatened with this question of teacher replacement, we think the same thing will happen here as happened in so many other places. It is going to allow the teacher to work on Monday with Johnny because he is having trouble, but not with Johnny all week, because he is only having trouble on Monday, to work with Mary on Wednesday because she is the one who is having trouble, or with Jean, who is absolutely brilliant and has just gone through all the material that the system would allow and can take on something else. In other words, we hope that it really will, more than just individualize instruction, it will really allow the teacher to interact with the students as they need it. I really do think it holds great promise. As many of us, I issue a lot of caveats about this, because it's not proven yet. We haven't had enough experience, we have a great deal to learn. I don't think it would be a great service to the whole effort of education if we were to start to push this today as being fit, and proven, but on the otherhand we are getting more and more self confident about it. It has been almost ten years that research into such methods has been going on at a serious level, which is a long time in this age to be working on something. It does appear to hold the promise of not having to choose between individual and group instruction. I will be the first to say that I have yet to find anyone who can tell me how much individualized instruction is good and when it becomes bad, vis a vis not having sufficient group contact and so on. But I will leave that to others who are making that their profession. But it is very promising and at times does help. Let me point out that the reason I am bringing these several things in. I think that the classroom in 1980, or whenever that golden day comes when they are making appropriate use of these tools, will employ a constant intermixing of problem solving of simulation, games tutorials, and some of these other things, and there won't just be a particular type of CAI.

I will just go through some of these quickly because I don't see how you can ultimately separate any of them. Information retrieval - there are two obvious things that are worth repeating about the value of using the computer in the educational process for greater powers of retrieval. One is the obvious one, that knowledge is becoming so voluminous I notice that the gentleman from Xerox is about to reduce to a computer form some 196,000 Ph.D's doctorial theses, which will allow retrieval by dial, access anywhere in any educational institution of what otherwise would be impossible to obtain. This suggests the possibility of exposing students to a great deal more material. Just as important by giving him more time to learn, or whatever else he wants to do. In certain disciplines, like the law, students just spend literally untold hours, climbing over those stacks. You can eliminate that. You either give him more time to hang around with the girls in the sorority or learn, (that's up to him). It looks like it has tremendous powers in this regard. By the way, this again is not something that needs to be validated educationally, as we must do with the tutorial approach. This is just getting the information for him, and I have not heard any dissenters on that score. The real test here is getting this material reduced and that is a fantastic job, but it is moving ahead, and learning the techniques by which we can properly access to material. An important thing is giving the student access to the equipment and the data bank, which will allow him to use it in the educational process. And finally, most importantly, is working that into the curriculum, the day to day teaching process.

Now, another area, which again absolutely cannot be separated out from CAI, in fact it is inherent in CAI, is testing. What you see on this chart is something that those of us in the computer industry would call a sales analysis. When we were back selling punch cards to businessmen, years ago, the way we would sell it to vice presidents of sales would be to tell them, look if you can record all the data on your sales on punch cards, we have a sorting machine that can sort the cards down and tell you what is being sold by all of your salesmen, by each salesman, how much he is selling, how much is being sold of each product, how much is being sold in various geographical areas, and so on. You can analyze data in many, many different ways. And the same thing is true in testing. Now this has already been done in the United States and other places, both commercially, and non commercially. It is possible to analyze a test, for example as to which questions involve concept grasping, which questions involve problem solving, which problems really depend on knowing your homework, and which questions were a result of being able to read well, and so on. If the tests are properly structured, the computer can then very easily provide the teacher with these types of analyses. Where the teacher finds that a student is very high in concept grasping but he just consistently strikes out on problem solving, she can guide him in his career and future studies much better. Similarly, this is very easy to determine, by a simple computer run, then she can change the test, and so on. The point again here is that it is a tremendously powerful tool if we can really begin to employ it. It really is an inherent part of this tutorial dialogue, because what happens in a tutorial dialogue is the way you ultimately structure the program. The system if it has been structured, if it has been structured, is really doing this. It may be branching the "concept grasping student" into problems deliberately, if that is the purpose. If you want to get the student who is obviously failing when it comes to reading questions, perhaps feeding more reading to him and less math, until he is doing better is indicated, and so on. So again, there are some tremendous possibilities in the area of testing.

This morning's New York Times is full of lots of news. They discuss the work going on at Harvard, including a computer based vocational guidance program. Professor Tiedeman at Harvard is also working with us because we have a program to do this also. It is a noncompetitive program because theirs is more research oriented than ours. What we are developing is a program and a data bank which will allow a student to sit down at a terminal and feed in his own background, in terms of academic performance, interest, and the like, and then query the computer about what's it like to be a lawyer. From the data bank can come the information on what a lawyer does, what a lawyer's salary is, what his lifetime earnings are, what schools prepare for law, what the normal requirements are for this type of profession and how it matches the particular input that the student has already made. Fundamentally, counselling at the level I am speaking of, is really a great information retrieval and matching effort. Having been exposed to this, the student would be provided the opportunity to go to a counselor and sit down and discuss with probably a much better foundation of information. We are quite optimistic about this particular one because, it really is rather simple. I have talked to counselors, and one of their problems, is just staying up to date with what is going on in the various professions and vocations and so on, staying up to date with where you get the information on colleges, and who is teaching what, and what are the entrance requirements, etc. It could frighten an awful lot of teachers by the way, because it does suggest non-individualization and the non- humanistic approach but it does suggest that if you could optimize the needs of the individual in a society like the United States in light of the requirements for the society, you could probably make a significant impact on the productivity of that society. Practically, any improvement you accomplish should be of some assistance. One could argue that if you took the computer and used it for just one of these various things we are talking about, you might encounter a significant impact on the whole process.

I think you know, the computer has been around a long time, particularly in higher education and the administrative process. I would like to mention just one thing, in the student scheduling area, the University of California, at Irvine, as I mentioned earlier, has been doing some very interesting work.

In the instructional process, they have over 75 course segments now being taught to some 1600 students on terminals. There are 1600 kids out there, they are taking economics and geography and spend a certain amount of time each day on terminals. Later on you ask these kids how they like it, and they look at you like you're nuts. "We like cars and telephones and this is how we take geography, so what else is new?" And this is a very new university, three years old. But they are going great guns. They've started their students scheduling in real time. The students come right in in the fall to the administration building and have two or three alternative schedules made out, they type that into the terminal, and immediately the student either gets what he wants, is reassigned, schedule is set, the files of the various classes updated and the next student who comes on now is ready to be scheduled in the newly updated system. This year, I don't think they did their whole student body, but next year they probably will.

The thing that impresses me most, and I guess most educators I talk to, is a fundamental lack of understanding of the learning process. The reason it affects us is that we want to develop a product. We go to people and we say: "Is it better to have visual or audio? Should you have inquiry method, or should you have lectures? Is it better to have a long period of time on a visual terminal or not?" We just don't know enough about these things. It becomes quite complex as you all know much better than I, but the interesting thing is, and a happy thing we think, is that the computer itself provides perhaps the best device by which to do this kind of learning research. The Brentwood installation that Pat Suppes has is as much devoted to research, I don't know whether it will ever prove to be the model for teaching. However they hope to finish the testing in a week or two against the control class and they are highly oriented to research. Every time a student makes an answer, they are able to time it, they are able to record a great deal of data on what that student is doing. Later, it is all in the machine in usable form, so they develop another program to reduce this data. They have developed a number of programs to summarize this data. They are doing as much in this area as they are in just trying to validate CAI. They are trying to use the computer to understand better how these kids learn, and what stimulates them to learn and so on. This is an outgrowth of CAI, which can close the loop and feedback into how you had better prepare the program.

Amoung the problems that face us, as we see it, are some of these: Understanding and acceptance is going to be a serious problem, and it is here that I think the most caution has to be exercised by industry. I think that most of us in business are not used to the environment of education. It is clearly a different environment from the business environment. The businessman thinks in terms of profit, educators think in terms of efficiency. They can be sold on that basis; the teacher, if she is a good teacher, thinks in terms of an individual, of a better person, and I think the average teacher rightfully is very suspicious that the profit motive is incompatible with the goals of education. And therefore I think that business stands a fair chance of losing. If it does, I think that education stands a great chance of losing. We must find a way to enter this environment in a sensible way, recognizing the differences in it, not pushing these things too hard, validating them. I think accepting a slower acceptance rate in the beginning, we will result in a faster acceptance later on. The acceptance problem isn't difficult in some places, because there are some places that are naturally innovators, but when you come to the average classroom, the average public school classroom, where I think the promise of it is so great, this is going to be a very real problem.

Funding for the time being is going to be a very real problem because we still haven't got the equipment in the schools. At present we have equipment costs at a level which is reasonable but still out of reach for many of the things that ought to be done with it in education. We have made quantum reductions in the cost per student. If you examine a history of computing, we have made fantastic reductions in the last fifteen years in the cost per calculation, that you will have confidence that the equipment cost will come down. It is merely a matter of time. It is literally exponential in the terms of calculation cost, in what we call cost of performance.

I am impressed by the fact that at the end of World War II we were putting something like 2 or 2½% of our gross national product into education, and now we are putting over 6% into education. This report of the Brookings, which came out with a statement that education has had the single most important influence on the growth of the gross national product, some 23%. It suggests to me that we shouldn't be so terribly worried if the costs come down, I think the society is going to put more in. The place that is going to be a problem is in research and development. This must be developed through the traditional sources in my estimation. It should not be developed by businesses, it should not be developed by publishing houses. Publishing houses in the past never have developed materials, I don't know why they should start now. We had a subsidiary publishing house, and we found that that's not what its for. Their part is working with the course authors, doing a brilliant job of editing and packaging, but not of developing the materials. So, it's our belief, rightly or wrongly, that you must take action to provide education, technical assistance, and incidentally, legislative aid to insure that the traditional course author has the ability to continue to be a developer of these materials. Copyright laws must protect the course author. If no, we are going to stifle progress and we are going to impoverish the quality of the material that goes into them.

We are at the point now where we are putting some good results, some pretty bad results in CAI. We have a number of joint studies now with several universities. Some examples are, of course, Stanford, Texas, Penn State, Florida State University. These are all universities that either have systems of their own installed or have terminals. IBM has just embarked on a very extensive research program with the State University of New York. We will be employing a very large number of terminals throughout the various campuses of the state university to actually start using CAI on two courses that they are convinced now has great validity. We will start stimulating the development of further course material.

Question: "What are the courses?"
Answer: "German and French."

A discovery we made is that the idea of a language being a good CAI subject had a basis. It now looks to us like languages are tremendously good subjects for CAI. State University of New York indicates that they are now going to attempt to use as much of this as possible in their German next year, throughout their department. The French group immediately went to another publishing firm that has a very fine French textbook. They had taken a German program that took three years to develop but now you talk about the cost of materials, in less than a term had converted to French, and are now using the French. There is hope that if you do it one time, the next time you do it, it's a lot easier. It looks as though we could take virtually any language now and start to build on it. I mentioned the University of California at Irvine, let me just comment quickly on a couple of others. Florida State University has had a system installed for some time now, using CAI. Another developing giant is Penn State. They had someone publishing papers suggesting that CAI was worse than normal teaching, so I think you can also believe them when they say that some of the work they have been doing is very good. They envision a very dramatic number of terminals on their campus within a very short time. So does the Naval Academy, and the University of Illinois. A number of these institutions are very, very heavily committed. By the way, State University of New York, along with the City University of New York are very heavily committed, at very very high levels of the University, to the value of this and they are moving ahead.

In closing, I would just like to comment again that the only important problem that will really impede the pretty rapid acceptance of CAI is the approach that business uses. How business and government go about introducing this into education.. And I'm really convinced that if we do some intelligent things in this regard, if we set up, a code of ethics, and we are working on it, a standard of conduct which is different from what the average citizen is used to, if we don't unleash some of our sales people, who are pretty powerful salesmen, things will go well. If we make some real concrete attempt to work with the educator, consider him more than a customer for a long time to come, then we can succeed. This thing holds so much promise in my mind, that I would just like to leave you with a thought. If we succeed, the computer will become truly an extension of man's mind, as the machine has become an absolute extension of his muscles. And if we can take a weak muscle like this, and do what we have done with the machine, when the day comes that we can extend man's mind in the same way, I think the effects will be fantastic. And I would suggest that two things will happen when you use the computer in education. The first is that the manufacturer and developer of both the hardware and the software is going to have to develop a better man-machine relationship with the students, than he ever had to for business and science. This will make the tool better and easier to use. And when the day comes that man's great intuitive, judgmental and emotional capability can master the far greater capability than calculation and memory of the computer, on a real time basis, it is going to be a tremendous day. The other thing that I think will happen is that when you achieve this good match of man-machine and you have a generation of people who from kindergarten to their Ph.D thesis are accustomed to just using a computer for various things, as a normal every day tool, you will have a generation of people who will have a vastly greater mental ability than they have today. To me the ultimate promise is there, and not just in the field of education. If that may be a little bit too optimistic, forgive me, I am very convinced of the capabilities.

Dr. Martin is a former school superintendent. Although recently become an "industry man," his thinking has been shaped by a long career as an educator and scientist. His particular concern is with motivation in the learning of basic language skills. For the young child and the culturally disadvantaged, he focuses on a multisensory approach to achieve student interest and effectuate learning. The software described herein differs radically in form and philosophy from classical programmed instruction. Further, it is part of a larger system which includes the regular classroom teacher and auxiliary learning devices to make an effective bridge between the conventional school and CAI. Dr. Martin's presentation was not only a valuable addition to the Seminar in itself, it demonstrated some of the controversy and the divergencies at work in this rapidly evolving field.

Dr. John Martin

I liken the computer to a brain, and essentially a disembodied one. I find that one of the great flaws that has crept into the field and stayed with it for lo these 10 years, is that much of the thinking is exemplified by the language that continues to be used, language that refers to the point at which the learning begins as a terminal. So the thinking has been supplied by people who sit inside the computer and recognize its capabilities, and looking at the neurological cord, connect it to a booth and call that booth a terminal. And this is psychologically at the root, I think, of much that has not happened in computer assisted instruction. This constitutes a serious neglect of the interface or the beginning point of learning. Thus the computer has fantastic capabilities, a half dozen pieces of which we saw a few moments ago. I am also particularly excited over potentials in problem solving learning, and in that proposition called simulation. I am very excited about it as an information storage and retrieval system having to do with record keeping and behavioral analysis and diagnosis having to do with the whole field called guidance, whether vocational, personal, etc.

I find that when we talk about computer assisted instruction we do focus on the learning aspect - that is, the computer as an instrument for teaching. To have learning occur is our goal. It is that aspect that I want to talk about and talk about somewhat disparagingly with my introduction of the semantic question of why computer assisted instruction on the tutorial level is rooted in the limitations of the technology that gave it birth, rather than in the educational art of learning systems which should have focused on the nature of that terminal. People are stuck with a kind of linearity of thinking from inside this disembodied brain, that activates something at a point called a terminal. This impoverishment of that terminal is rooted in that kind of thinking, and that is why tutorial instruction or computer assisted instruction is the narrow concept that it is.

I sat in on a meeting at a major electronic firm that for two years or more had a very serious working relationship with a professorial team on computer assisted instruction. At the end of a long afternoon, in an examination of what it is that they were trying to develop, the research manager for the industrial unit turned around to the professor and said, "When you people get around to telling us what it is you want, we'll build it." Now that is after three years of such intensive work. The point of his expostulation was that they hadn't described to the technological experts, the kinds of behaviors they wanted the computer to activate. That is a key element in our discussion. The disembodied brain that I am calling the computer must, at its terminal point, make things move and happen that are in consonance with even the fragments of learning theory that we do have. And the absence of that kind of a disciplined analysis of the "inter-behavior", between the terminal and a learner, absence of a disciplined analysis of those behaviors was the single most important regression, suppression, deterioration, non-development of instrumentation.

Let us consider some history. Omar Moore, with a child needing cosmetic surgery, activated by his own impetus for problem solving techniques, under took the tutorial job of teaching his child at 2 years and 10 months to read. Subsequently he picked up a couple of other professors' children and experimented with them. Many of you have seen that amateur film that he produced called "Early Reading". A manual exercise using an electric typewriter and interposing between a child and the typewriter a human being at a cut-off switch and the behaviors of the person operating a cut-off switch to an electric typewriter manually, were the products of Moore's theory of how learning took place. By an historical accident I was then consultant to the Edison Laboratories in West Orange, and we had spent some 7 - 8 months analyzing the consequences of Skinnerian theory for possible technological instrumentation. I may say immodestly, one of the few times in my life that I came to a very significant conclusion, was when I advised the laboratory that Skinnerian theory of learning as a basis for the construction of a technology to exhibit materials to be learned had serious limitations. I did not quite have the forecasting capacity to use the term which subsequently came out two or three years later, that Skinner really means a different way of printing a book.

But at any rate, at the laboratories we had examined frame presentation, framing techniques, withholding the responses, controlling the movement of the machinery through the next frame of presentation so the correct response was there, etc. And I computed the kind of hard-nosed school teaching capacity that a high school of 500 children needed: it would occupy X number of cubic feet, and the warehouse needed to warehouse the alternate programs to service

500 children would be in the order of two to three times the sheer volume of space occupied by the human beings. And if this now were encumbered with mechanical or electronic feed mechanisms which feed a piece at a time, a bit at a time, a frame at a time, that this was a technological dead-end. That was about 1959, which as these things go, is a hundred years ago in the state of the art. I said to the laboratory, what you need is what I don't have; that is, you need somebody who is spending his life in a really important examination of behaviors involved in learning. And you need a greater complex of learning theory than Skinner has found. I do not mean to denigrate Skinner. I liken it to that old saw of the Hindu fable about half a dozen blind men, each reaching for a part of the elephant. I touch a piece and say, "I have found the nature of the elephant; it is like a snake; I found it, it is like the trunk of a tree", etc.

My observations of the nature of learning theory , is that each fragment of human behavior discovered is part of the complex, for which we do not yet have an overarching, total theory. We have fragments. Each piece as it is discovered will produce a significant increase in the quality and the efficiency of learning. This is what happened with Skinner; it happened before with reward systems, and it is now happening in the behavioral sciences - instant reward systems, for example, and different kinds of rewards systems for prompting behavior situations.

So what I am saying is that this is a prelude to a kind of technology: that instrumentation to influence, cultivate, activate, and interact with the learner, must be based on whatever series of pieces of human behavior are involved in learning. Inevitably it is shaped by them.

I found Moore at a small meeting, and he had about 4 minutes of film clip of what he was doing. I got that film from him, turned it over to the laboratory, and they married each other. Kobler and Moore produced the talking typewriter, and today I am with the company - the inevitable course of the devil's hand. It served me right you see, some seven years later. The instrument that we are primarily concerned with is multisensory. We are developing others based on the same working principles, in this case meaning behaviors of children involved and behaviors of human beings involved. I might just simply say in over-simplification, that essentially we have instruments, or this particular instrument, that is multisensory in its involvement. That is, the more of a human being's senses that are involved either in sequence or in coordination in a behavior act, the more efficient the learning will be, and by efficiency I mean both rapidity of learning and length of retention and understanding.

Secondly, if the learner is actively involved in the process of that which is "presented" by the instrumentation, again efficiency will be increased. That is why, for example, the television screen is not a particularly efficient instrument for teaching or for learning. Its effectiveness in the mass culture is its fantastic redundancy, that is, redundancy in time. Children of today spend literally as much or more time in front of the television set as they spend in formal learning processes in schools; so that the impact is a pounding impact, it goes over, and over, and over, and over again. But as an instrument for teaching, its limitation is that it does not bring into the learning situation the behavior of the learner; it is a passive device. This passivity limits it effectiveness. So I am emphasizing multisensory and multiple involvement - kinesthet, tactile, and vocal.

So what we posited is an emphasis on the interface, this instrumentation mixed with the learner, by examining very rigorously, very pragmatically, and critically, what happens in the child's learning. The instrument itself was available in 1961 essentially as it is now. For the first 5 years they very judiciously and carefully permitted single instruments, at most two instruments at a time, into a variety of situations to test the limitations and the parameters of its operation. I undertook the first public school research effort within the field at that time in Freeport, Long Island. We are now moved into largescale operational use, and I will begin talking to you in a minute on how we designed what we think is a comprehensive system for its employment.

In the course of these examinations of smallscale use, the dexterity of the instrument became in effect a problem. It does not require a FORTRAN or COBAL program, the machine can be commanded, or programmed in the English language. Because of this tremendous ease of commanding it - and I'm using the word command instead of the standard word programming since commanding is a process of describing and requiring the multiple machine behaviors. That is, it talks, it shows pictures, it shows drawings. What I'm saying is that commanding the instrument, programming it, in effect, requires not even the teacher. A layman that can be made technically competent to command the machine to talk, say this, show a picture, make the typewriter operate, have these responses vocalized, give audio-channel response, proceed in an orchestration of these various media; or to use what I would call an activation of the learner's different senses. Because the machine was so programmable, the need for standardization of programming - and I'm using that word cautiously - did not become apparent until the instruments were placed in largescale installations, as they are now operating in Chicago and in Brooklyn. What happened was a flow of children or adults, depending on the time of day, in a sequence of about three an hour. With 20 minutes in an installation, you can readily see the simple logistics involved: 60 people in an hour, and another 60 in another hour, then another 60. The concept of individualization of programming begins to break down when you envisage that every one of 500 people in daily attendance on instrumented instruction shall receive a custom-tailored program based on his previous experience with the instrument.

We have a tendency in education to see the generalization as a universal truth universally applicable to all people at all times, having derived it from a careful statistical study that said that this generalization is a good one because it is slightly more true than it is false. But education makes a perpetual quantum leap. We say all children are different, and all children are the same. We say that programming needs to be individualized, and programming needs to be standardized. We walk a kind of a see-saw alternation of ridiculous extremisms in both cases. So what I take as base is standardization of program design based on population type and age groups. This then permits custom-tailoring for the children for whom, as they go through this program, there is in effect a hang-up, a fall-out, a resistance, a noneffectiveness of teaching. What we are finding is that in a given 100 for example, there might be 7 or 14 or 11 for whom the linear program is not optimally suited. The fact that the instrument lends itself to rapid customized program variance from an essential core of programmatic material, is an asset that straight linear programming, even computer stored and based with branches, etc., can't begin to approach.

So we have been in the process of developing, and have recently completed what is to my knowledge the first pre-school through first grade reading program which is fed through an instrument that calls for multisensory adaptation to a multi-media presentation. We are getting some very extraordinary results in the slum situation in New York as a consequence.

Incidentally, on the question of copyrights, we've moved corporately without firm long-term policy and with a recognition that we have to produce the software. I am not talking compatibility; obviously nothing is compatible with our particular instrument. The commands and language used are not transferrable to a computer, at least not by a simple adaptation. Adaptation is possible. What I am talking about is that the programmatic state of the art is fairly miserable. Essentially it is based on Skinner. Most often it is a straight question and answer technique. This happens because the technology insists that the material be presented at bit at a time; that 95% or better instantaneous learning take place; that the error margin be in the order of less than 5% before the machine will proceed to the next proposition. This all exists almost exclusively in a printed mode - whether or not the print-out is on a CRT or a piece of paper is of no consequence as far as we know in terms of the impact on the learner. He is looking at symbol language, whether the symbol language appears on a piece of paper, or a cathode ray tube. No one has bothered to step aside and ask if there is anything intrinsically important to that presentation mode, whether it be on paper or CRT. I think the answer is that the CRT exists simply because a teletype print-out of a paper is a little bit more cumbersome perhaps than the greater dexterity of the CRT for future programming uses. This is not true currently in the state of the art of using the CRT. With a CRT you can eventually produce a picture or line drawings, you can't do that in a teletype print-out by the computer activating the typewriter to produce line drawings or pictures. Currently, however, what is being put on cathode ray tubes is essentially the same material that goes on paper. And that is extraneous to the question of what happens to the learner. No one knows that answer.

The state of the art of instructional programs has not yet included the orchestration of audio, visual, pictorial, graphic, and print-out in symbol language (presumably at this point you are talking about the English language, or the language of mathematics). As a consequence the material, the software, as it currently is being exhibited, (and this may not be true for some of the installations that you will see, I'm only talking for my current level of knowledge) is a very emasculated, very poor piece of pedagogy, essentially cathechismal in design. It is essentially a bit by bit presentation with emasculated pictorial material and essentially without really organically examining when doe the computer talk, when does it print, when does it show a picture, and when does it provide for an interaction by the learner as an intercession in the several media.

The instrument we have forces a break in that mold of simple linear bit by bit presentation. For you have here in front of you a multiple instrument, capable of making music. It is as if you made an analogy of a typical program to a music score, and gave that to a conductor to use, and found that with a 100 pieces sitting in front of him - a string choir, and woodwinds, and percussion, and so on - the score only called for music to come from some 6 or 7 of the instruments while the rest of the orchestra remained quiet. In our case the apparent silences of the non-use of the instrument's capabilities is so instantaneously apparent as to compel a broader look at the pedagogy of the program. By pedagogy I mean the behavior of the instrument now in effect simulating a teacher. The failure to see the terminal as an active teacher intervening and interacting with a learner has emasculated the concept of how these instruments should behave. So that if we began using the term to free ourselves of both the Skinnerian history, not hostilely, but simply to get a broader view of the learning act, if we begin talking about making instruments behave, then programming, it seems to me, would lift itself to a higher level or art. We could overcome inadequacies of CAI in two fields: technology where new kinds of instruments at terminals would be demanded instead of the primitive ones that currently exist; and in software, we would have a sophistication of multiple behavior-requiring presenters, or multi-media, or to use the language I prefer, the multisensory involvement of the learner. The exploitation of technology to get this kind of interaction would move much more rapidly than it has in the past five years.

With this talking typewriter, which is our major product currently, we have evolved a working system to supplement the current educational process. We are pushing vigorously for a concept of the learning center as an auxilliary to the existing constellation of schools in a particular geographic setting, essentially in the large cities where there are many schools physically close to each other. We are asking school districts to think of these learning centers as physically independent of the normal educational plan. There are pragmatic reasons for this: typically school plants are overloaded now to the point where physical space restrictions are horrible; the other reason is that we do not want our process frozen into a pattern where the institutional behaviors already existent in a particular school situation can emasculate its progress. We decided to use space over a shopping center food store, something less than 10,000 square feet on the second floor of by-pass neighborhood areas - the chiropractor's office type of second class office space. Secondly, we wanted involvement. The old pattern of the PTA, and such other relationships as the city population to its schools are broken down and inoperative in most cases. I can say from a good many years of experience that this Pollyanna charade of parental involvement is an extremely ineffective waste of time.

Yet American education has rested its pedagogy very heavily, despite volumes of rhetoric to the contrary about motivating children, on parental anxiety that a child learn. And the public schools which succeeded in teaching children best whose parents wanted them to learn the most, and has historically failed most miserably with those levels of the population where parents are indifferent, ingorant, or hostile. The most noteworthy examples of that, of course, are the Indian and Negro populations. Our previous immigrant groups had a history of tremendous anxiety about and emphasis upon education. Those immigrant groups in large part sent children to school determined to learn as a manner of economic escalation. Despite language handicaps, etc., the schools did magnificently for such children, backing the schools was the parental motivation. Any system of learning that ignores parental involvement assumes a weight of consequences in terms of what will happen in the institution that has to carry the load of getting the children involved in learning. What we are describing here is an institution operated by the standard Board of Education, or the welfare agencies, or poverty agencies but providing a new form of parental involvement. We have an advisory board of parents for the centers. Another aspect, but an important one, is that historically technology has made its way as a saving in relation to high labor costs. With our instruments, our supervisory personnel or the child in the machine learning situation are layman trained by us. Their backup supervision is done by a teacher with experience. The ratio is in the order of two such professionals for each ten layman in supervision of twenty children in the act of learning. The layman's wage rate runs $2.00/hour generally. There are new jobs for the laymen. We have a beautiful semantic term for them - educational technicians. The common place language today is paraprofessionals, etc.

This is a community and parental involvement, fortified by the using of a class of labor with lower cost than previously. The shoemaker who used to be a bootmaker and made the whole shoe is now a cutting machine operator who stamps one piece of leather in the complex of putting together the shoe. The impetus for capital investment in any productive enterprise has always been an increase in productivity and diminution in cost per unit output with a change from the high priced specialist into the lower cost generalist, or the production line person. Failure to recognize this as part of a systems analysis of the learning process is to go in the face of the historical role of technology. We had arrived there empirically but I am now giving you a theoretical explication for it.

The construction of the software we are currently involved in by agreement with publishers is what I call a kind of software piggyback ride. We have taken the Bank Street Readers of the MacMillan Co. which is the officially adopted text for the city of New York. It's better than a standard textbook series in reading, it's ecletic, which is a way of saying that it's not overwhelmingly "look", "say", or phonic. It is a fairly judicious and well-thought through mix of these processes. To my knowledge no one is beginning reading on a computer. We not only are doing this, but we are doing it more successfully than can be done in a regular school situation with the full range of the kinds of children that come to the schools, from retardates to the very bright, from the culturally disadvantaged to the middle-class income child - if that means advantage.

But in doing this we discovered a phenomenon, an old one to school teachers, but I will say it outloud because it's been ignored by the software people in the field and in the field of technology in particular. A reading series consists of a series of volumes that are placed in the hands of children from the softback pre-primer or so-called readiness materials, the primer, the first grade reader, to the second grade reader, etc. This is supplemented by another book which reminds me of my college professor's description of French grammar. If all the rules in French grammer were put in one book, the book would be that thin; if the exceptions were put into a separate volume, that volume would be that thick. Typically in a reading series, the teacher's manual is the same magnitude greater than the material in the hands of the child as exceptions are to the rules of French. In the manual are the author's prescriptions, or if you will scenarios, for the teacher to bring alive the reading text material in a learning situation. And having been long-term associated with publishers and authors and people in the field of reading, I can say to you that the universal bane of every supervisor of reading in public schools, or of publishers and their authors, etc., is expressed the universal cry, that if teachers would but slavishly follow the manual, literally line by line, the quality of instruction in the classrooms would escalate on the order of 4 or 5 times. In our manuals is imbedded what we would call the reading skills distinct from the surface reading material, or stories of the text. So we are now completing two parallel linear reading programs. In one we have programmed the pictorial, the verbal, and the written material, plus the audio relationship with the child, with a careful planned intercession by the youngster in his operation of the typewriter in response. For instance, if a particular lesson - a picture story - has as one of its raison d'etres that beginning consonants are to be taught, descriptions of the behavior of the teacher to elicit the exercises, to have the children hear the symbol sound of the hard c and the k and the g, etc., are programmed in parallel fashion. The children move in a kind of an interlock between the high-interest, high-content material into what would be called in duller terms the drill exercise of the actual skills of the acquisition of the reading process.

Our corporate position is that we will release no additional instrumentation for learning without simultaneous capability in software. We will not sell one without the other, although all our instrumentation provides a high degree of flexibility for self-programming by the customer. So we encorage self programming, but we insist that as a hard base - and this has nothing to do with commercial aspects because software is probably a costly give-away at this stage of the operation - we insist simply that there is no reason why the next 10 years should repeat the high crime and misdemeanors of sad software in happy hardware, which is where we are largely in the industry today, despite ads and other presentations to the contrary.

For the movement of children and adults to these centers we have evolved, we recommend strenuously that classroom teachers bring an entire class; that the teacher come along; that these centers contain auxiliary classroom space. In the auxilliary classroom space we have a high concentrate of the other standard audio-visual materials, that is, telephones, tape recorders, the 8-mm projectors. We involve the teacher in the process. During their hour at the center, the children go to a booth for a maximum of 20 minutes. They return with the tear-off sheet off the endless roll from the typewriter. In other words, the child comes back with a physical record of what he has done. A carbon left behind becomes a part of the permanent record kept on each youngster, plus the booth attendant's behavioral observations of the youngster - in short, telegraphic simple language. This compels the teacher to a recognition of where that youngster is today. A simple visual review indicates where difficulties, repetitions, etc., take place. You might say of the instrument by the way, if the program is so set as they almost always are, that it does not permit the child to consummate an error. That is, he can attempt to depress a key misspelling a word, or irrational to the word entirely, but the instrument does not permit the consummation of the key pressing. The machine can also be put into a free typing situation, but our programs do not allow this at present. In addition the teachers are encourages to leave the classroom intermittently to observe particular children in the booths. One-way glass makes that possible, plus earphones for audio overhearing. The teacher is supplemented by the center's own aides, the laymen who make possible small group and tutorial supplemental instruction. Using the basic reading series of the system; involving the classroom teacher in the program; giving the teacher an instant daily print-out of the youngster's progress; providing a climate independent of the regular classroom, which makes deviations from institutional behaviors possible and in fact encourages and almost mandates this; all make the center a very effective in-service training place for the teacher. So while the system supplements and complements the regular main curricular flow and intent of the school in its language arts development, the center in effect charges a price by becoming a change agent in upgrading individualization of that instruction. So we have the happy circumstance where the teacher is exploiting the instrument as a supplement to her own effectiveness. And you can see that all the spinning jenny anxieties about technological unemployment are reduced, and we have had no response of that sort to the participating staff.

If you want data, which is generally difficult to obtain in this field, I will give you some. I ran the initial experiments with public school children and kindergarten children from Freeport, now some three years plus ago, and published a report called "The Freeport Report". We exposed 22 children in the experimental group against 22 in the controls, and wound up 4½ months later with 22 transfers. The selected population ranged from 4 in the mental retardate group (53 to 72 IQ) through packages of 3 and 4 over the range of IQ's up to 140. We did what to my mind needs to be done in every educational experiment, and I scarcely can remember another time when it has been done. To obviate the Hawthorne effect, the teachers in the classes from which the children were to be withdrawn for the talking typewriter instruction, were encouraged and trained in beginning reading starting a year and a half before. They had 10 to 12 years teaching experience, superior teachers by everybody's standards. They operated in classrooms superlatively equipped in terms of materials, etc., and they were given a John Henry exercise in that they were told to see if they could beat the machine. So the control children were not, as in ordinary educational experiments, given a placebo of nothing and then 5 months later the experimental group, always to everyone's happy surprise, inevitably turns out having accomplished more. In this case the control group was given their head. An attempt was made, without supplemental instruction of any kind, to see whether or not technology could teach as well as the best teachers in the business.

Statistical results were reviewed from the raw data by an independent - I sound like one of those commercials - statistical outfit. There was a large statistically significant difference in favor of the machines. I would have been satisfied if there had been a large statistical difference in favor of the children in the regular classrooms provided from the interest of the experiment, that there had been any great growth or change at all as a result of technological education. In this case the machine did better than the best the teachers could do. The results we are getting in the field now are all subjective observations, but they are measurable. The group of high school youngsters were picked by the high school principal in the area. If you know anything about education and high school principals, you know what he would pick when asked to pick non-readers. The attendance records prior to their inclusion in this learning project indicated truancy on the order of 50 to 80%, and their attendance has been turned around.

The district superintendent reveals the neighborhood history that scarcely 25% of the first graders in the several schools in the area finish first grade material in June. The current operating picture is that better than 80% of the children involved in those same first grades will do remarkably well at completing first grade material this year.

So we think we have a system. We think we have a process. We think we have also, temporarily at least, cut the umbilical cord between the brain over here and the output devices over there.

Dr. Lewis: "Is there any computer involved in your operation at the moment?"

Answer: "The instrument itself is analog based."

Dr. Wilson: "When you talk about multi-media, and the use of different times in the learning process, how do you know when to do what?"

Answer: "Our programmers, as experienced teachers, take a body of material and the manual that prescribes teacher behavior, then postulate the sequences of behaviors they would use in the tutorial position with a child. They write those down as behavior commands to substitute the instrument for themselves. That is, they note when they would show a picture, when they would say something, when they would have the child write. This becomes the sequence commanding the behavior of the instrument. It is encoded, put into the instrument, and tested against a group of children. Then observations provide the annotations for a rewrite. I set the limit of one such rewrite, and that is it. We polish after a total, longscale run."

Software in the sense of the instructional program is at once the crucial focal point and most perplexing research area of CAI. Mr. Rogers, from the vantage point of a company where computers are not produced but training programs are, offers a lively and penetrating presentation of practical problems involved in instructional systems, as well as description of some of the wider educational potential of the computer for information retrieval. He deals with the compelling problems of copyright, funding of educational technology and programming theory. Dr. Rogers describes several effective training applications of existing computer systems. His forthright approach shows concern on the part of the industry for divergent learning patterns, and a sharp awareness of the need for continuing research.

Mr. James Rogers

I'd like to direct your attention to a list of areas in which the computer has been used in one way or another with instruction, forgetting for a moment class scheduling, accounting, etc.

We now have a service called DATREX, a doctoral dissertation information storage and retrieval service, which is now available and works along roughly the following lines: The University Microfilms, which is one of the component parts of the Xerox Education Division, has as its data base approximately 126,000 doctoral dissertations representing the majority of those written in the United States and Canada since about 1938. You can obtain from University Microfilms a cue-word catalog in any one, or all, of four broad discipline areas, and then by filling out what we hope is a pretty simple order form, you can list either inclusion or exclusion of various key words; you may want everything in metallurgy but nothing on heat testing, and you can specify that. You may list, if you like, specific universities, specific authors, or years if you know that the dissertation you are looking for was done some time after 1947: You can specify nothing before 1947. When you mail the form to University Microfilms it is key punched and goes into a computerized information storage and retrieval system which prints out a listing of all of the dissertations whose titles contain the key words specified. The listing tells you the title, author, university, year, and it gives you the page numbers from dissertation abstracts so that you can then go and find the abstract of the dissertation if you want to further for more detailed information. It also gives you the order numbers and prices for a microfilm copy if you would like to obtain the dissertation, or a Xerox copy if you would like to retain it. This is admittedly one small step in the whole area of information storage and retrieval. Now clearly it would be convenient to expand this data base, and to put in extensions so that not only doctoral dissertations, but other material could be included.

There are many problems in doing this. First, there are institutions throughout the country already doing this in the physical sciences especially, and in medicine. How to coordinate with them is not clear. University Microfilms, of course, has the right to the reproduction of the doctoral dissertations, but another problem is that you don't have the rights to material that you want to put into an information storage and retrieval system, you have to get them in some way or another. Now I am not sure if we want to discuss any further the problem of the copyright issue, but let me just point this out, not only for information storage and retrieval but also for computer based instruction: if the recommendations of the committee which has been studying this go through the Congress and the law passes in its present form, it will be considered a violation of the copyright simply to translate any copyrighted material into machine usable form. Whether or not anyone ever uses it, or retrieves it, or looks at it, or does anything with it after, seems to be unimportant. You will have violated the copyright by putting material into a computer.

The problems for the researcher in computer based instruction might become enormous. Suppose you have some curriculum areas that you would like to consider, and there are bits and pieces of reading things, or mathematics programs that you would like to look at. If you have 17 different sources of material that you would like to experiment with, you must negotiate with 17 different individuals or institutions before you can even encode the material to put into the computer for research purposes. These are some things that we must keep in mind when we talk about the kinds of materials that might wind up in a computer based instructional system. It almost looks as if one is forced to develop one's own materials, and what kinds of things can be worked out between curriculum development people and the owners of the copyright have yet to be seen. There are promising first steps along these lines. At the Stonybrook computer assisted instruction installation which the State University of New York and IBM have been developing together, several different publishers have been involved. The French and German language programs there are really adaptations of books, and in all cases IBM, the State University, and the publisher have worked closely together and very cooperatively to put this material into the computer. Let me say one more thing about information storage and retrieval, and then I want to go to some of the other issues. While you are out at System Development Corporation, you will be able to look at a computer based information storage and retrieval pilot project I believe represents one of the most advanced of these schemes. It is called BOLD, which is the acronym for Bibliographic On-Line Display. Their data base is some 2000 abstracts of items from the Defense Documentation Center, papers in the fields of aerospace, technology, weapons, etc. These are stored in an extremely large computing complex which serves SDC, and there are various kinds of modes. You can walk up to a cathode ray tube and to the teletypewriter keyboard that goes along with it and browse through what they have; you can ask specific questions like, "Do you have anything on these items?" and it will tell you what it has and print the numbers. A very effective dialogue can be worked up between the researcher and the file in a fast automated way. If you do have the time while you are at SDC, try to take 15 minutes and have them show you the Bibliographic On-Line Display because it's an intriguing system.

The mainstay of the Xerox Education Division is contracting with industry and government agencies for the design and production of specific training materials, or training systems. If we can be described as having a multimedia approach, it is because the behavioral objectives of much of the material that we have produced comes in many different areas and so we do not care whether we use computers, tapes, or visual materials, etc. What kinds of media we use is determined by the behavioral analysis of what it is that can be done.

Another component of the Education Division is American Educational Publishers, whom you may not know under that name, but who might be identified as the outfit that puts out My Weekly Reader, and Current Events, and those periodicals which go into public school systems. The latest acquisition is Professional Library Services in Santa Ana, California. Their interest is in the design and everything else right down to the putting of labels on the spines of the book, and in setting up libraries, including public, professional and other kinds of libraries. They act as a jobber with printers. You could say to them that there will be a school in operation in 1970, and after consulting with you on what is needed, they can design the whole library, have it brought in, and have the books on the shelves with the cards in the catalogue, and everything ready to go when the school is ready. They can include some computerized arrangements.

One of the topics that has come up again and again in these last few days has been the problem of who authors curriculum materials for computer assisted instructional systems. Another way of asking this question is, "What are these materials like", and there is a feeling that they are something like programmed instruction. In many cases, in fact, programmed instructional materials with very little modification can be put into a computer. It is clear that the problems of stimulus presentation, response on the part of the student, the evaluation of that response relates in some way to what has been done in the field of programmed instruction. In fact, when you visit Brentwood, if you get one of the brochures that they hand out there, there's a rather categorical statement that computer assisted instruction is programmed instruction. I am not sure of the validity of that statement. I am less sure when I look at Brentwood because I do not think very much of the applications on the computer are based at all on work in programmed instruction.

One of the activities of the Xerox Education Division I mentioned was producing training materials, and for the past six years they have been involved in this and have produced thousands of hours of programmed material and have a picture of the whole area required to produce these kinds of materials. For the development of an instructional program, here is what we have found are required in terms of staff member categories, but more important perhaps, what each of these categories of people do in their contribution to the program development. Let me just run down them.

For one program we need a subject matter man who knows the content of the material that is to be presented. A behavioral analyst then works with him in order to program the instruction. A programmer must come in to put the results in machine-acceptable form. Test subjects have to be used for evaluation of this work under a program editor who can change the instruction as indicated. You might want actors to imitate various kinds of voices for audio-presentation, and then, if you are going to get the group working together in a meaningful way, you might want to have someone who is skilled in scheduling and coordinating the work, a project administrator or manager. Now, in six years we have never found anybody who embodies all of these skills or who can perform all of those functions, and yet we hear of programs being published with one author. I think the point has been made before, and I won't belabor it. I think there would be serious priority questions that could be asked about the quality of instructional material in which one man tried to do all of those different kinds of things. Now, we carried out some studies on the time it took to produce programmed instruction material and we came up with a kind of a rule of thumb, that in order to produce one student hour of material like this, it requires about 100 man hours of work on the part of people in the main categories, which does not include the other people who may be involved. Lou Bright this morning gave us a figure of somewhere between 100 and 200 man hours to produce an hour of instruction. If we include the other people involved why our estimate there of 100 hours might be even larger. Bill Kilroy, the director of marketing for the RCA instructional systems group, which is organized in Palo Alto, and is working closely with some of the Stanford people, indicates that even when they are talking about drill and practice routines, their experience has been that it requires around 14 to 16 hours on the part of the author to produce about 4 or 5 minutes of the drill and practice routine. Now, let us just ask what the implications of this are. Suppose you walk into a school system and you want the teachers to produce this kind of material, who is going to free them up for 100 hours to produce an hour of instructional material? And where are they going to get the training in some of those skills - because I don't think anyone here would maintain that teachers are skilled in these areas.

This is a serious problem; is it fair to demand that the school systems do it? Now some teachers, curriculum advisors and others, are being used, but only under special circumstances. At the Brentwood installation, for instance, I think there are many more professionals - that is graduate students - coming in from Stanford, who work very closely with the teachers. I am not sure how much of the material is generated by teachers, but it is a very special set-up. What would happen if you walked into the normal school system and attempted to inject this kind of manpower demand for the production of these programs? I do not have an answer here, I am simply raising an issue. We can point to requirements and we can point to skill areas, and ask meaningful questions about where people will get these skills.

Perhaps work should start immediately on the design of instructional materials in these skill areas, either by teachers or by others in the school system, but even if that were done, even if these people had the training, the question is how they are going to get the time off.

The task of using the computer itself - and here we were talking simply about the design of the material - is perhaps not that much more complicated; that is, learning the language of the particular machine that you might be working with, is not that difficult. The difficulties come not in learning it, but in trying to use it to its full capacity so you are not missing any potential, but also there are problems of operating within the limitations of the language that you are using. The programming languages that have been set up so far have been criticized by others, and I need not repeat those criticisms here. They do restrict the instructional process in some ways, making many problems with their actual use.

The real problem is what is going to happen in this whole area: who is going to write the materials, where the skills are going to come from, and who is going to train the people that actually do it. The Philco-Ford Corporation consultants hired by the Philadelphia school district, as part of their job, trained the teachers in the Philadelphia school system to write programs, and instructed them about some of the areas of behavioral design which are important to getting such programs written. But if the school district which is already dealing with a computer manufacturer has to negotiate with another agency now to train the teacher, it seems that some more adaptable system could be used.

Let me go to another completely different area. Xerox Corporation does not manufacture computers; and we are not selling computer systems. We do manufacture hardware which goes with computers, which operates with them. There is one which is interesting that I would like to talk about. The device is simply called a computer adapter. It is nothing more or less than a Xerox machine hooked up to a computer in such a way that it can take an 8½ x 11 piece of paper, put it down on the Xerox machine, and push the button, and instead of it printing and sending out, whatever is on that piece of paper is stored inside the machine. At any later time, then, you can call for that piece of paper with exactly what it had on it. Now let me immediately qualify what I have said. This is not optical scanning in the sense that an optical scanner or a magnetic and character recognition scanner looks at your check, or your utility bill, and stores that information in the computer itself. All that we're doing - it's a very primitive kind of approach - is simply to translate the light and dark areas on an 8½ x 11 piece of paper into 0's and 1's and store them into the storage area of the computer. There might be a lot of white space, a lot of areas stored, and so there are ways of compressing this so that you don't use a million bits in memory to store one piece of paper; the zeros, the white areas, are compressed by simply counting the number of zeros and storing the number, which indicates how many zeros there are so that when it is reproduced it is all filled out. There is one further thing that can be done. Alphanumeric information is stored in the memory of the computer in the usual character form of an 8 x 8 bit frame, and if you care to store within the computer a dictionary of light and dark areas in terms of O's and I's, you can in effect print out anything within the computer on this Xerox copy arrangement.

Now you would never do this for mass printing - no payroll checks, no utility bills, no big volume will ever be produced this way. However, if a student is looking at a cathode ray tube, and there is information on there which of course has come from inside the computer storage that he wants to keep, perhaps it might be valuable to have a button so that he could push the button and whatever is displayed on the surface of the tube comes out in hard copy. Suppose we use this device in a computer assisted instruction environment. What it would allow the instructor to do, for instance, without having to keypunch anything or code anything at all, is to draw a graph, make a map, a chart, or get a table of values for use in a problem, and take them and store these, and simply put them down and push the button on the Xerox machine to make them go into the computer. And then, if the computer assisted instruction language for that computer is modified to allow it, at any point in the course you can call for a particular piece of paper coming out.

There are cheaper ways of doing this, by pre-printing the information and storing it on a shelf, or by handing it to the student in a book. I am not suggesting that this is the most economical way for these particular examples, but there is one thing that you perhaps cannot print out and pre-store on a shelf for a student in a situation like this: a reading assignment, or a homework exercise, or some such material which is based upon his progress through the course up to that point. Assuming the students would be going through this material at their own rates and if a student has, let us say, 20 minutes given to him on a machine, at the end of that 20 minutes the assignment which is appropriate for him will be different. If it can be assembled in the memory of the computer on the basis of his performance up to this point, it can then be printed out for him so that he has something to take away with him. What the psychological difference to the student would be, if at any time he could push a button and get anything out that he feels is important which is being displayed to him, I do not know, but I think educators would like this idea. They might think that the student would feel as if he were more in contact with things if he could have hard copy print-outs. The device is brand new. It is a very primitive one, and so far our efforts are in the prototype area. But it is a device which might be useful in the computer assisted instructional setting.

In running through a whole series of random topics here, let me approach a question which came up yesterday, and which is underlying all of the discussions that we've had so far, and that is the question of funding. Where is the money going to come from for all of the research that is needed, for the hardware, for all the people that are going to be involved, etc. Let me say first, I do not have the answer for you. But I want to show you a system here that is related, on slides. At first this will not look like it has anything to do with funding, but let me go into it a little bit, and I think we can see.

Back in 1961, before many people had heard about computer assisted instruction, and before even many other people had heard about programmed instruction, United Airlines installed a system with headquarters and a main computer in Denver, which consisted of 900 agent sets, scattered in United Airlines ticket offices all over the country in about 150 different cities. These were all connected in to the main computer and the purpose, of course, was to try to make some sense out of the mess of reservation data. They can key all of this into a little device which fits an agent set and the information goes right into a two billion character storage of the machine. It looks up to see how many seats are available, what class those seats are, and then if you say you do want those seats, the agent presses other buttons, and those numbers are subtracted from the store. It is a straightforward application in the computer area. This was installed and working very well, when the problem arose of how to train the 3,000 agents located in 150 cities to use this agent set. The agent set itself, as we will see on the next slide, is a fairly complicated piece of equipment. It looks like a big desk calculator with a punch card input tray at one side. The procedures, including the kinds of questions that you must ask the customer, are fairly complicated. A very straightforward, but extremely ingenious approach was taken. They allowed the agent set in the office to be used in a training mode. With certain information keyed into the computer, it took you into a training program which was stored in the program part of the computer, and that training program took the simulated data which you were working with and checked it with some simulated training data that was set up. You can imagine, I'm sure, the anxieties of the computer programmers who interlocked this system so that the training data did not get into the actual reservations data - chaos would have occurred. So some very serious attention had to be given these interlock features. But once this program was set up, it was then possible to train the agents using this device. Here we have a photograph of one of the agent trainees. She is learning to push the buttons. The card which is in the machine has gotten her into the program section and she is using the materials which the customer will produce for her, such as an Air Travel Card, and the kinds of requests that the person will make. Actually, the whole control of this process is not stored into the computer. The control is stored in a program text which the agent goes through, and the computer here is being used perhaps more as a simulator than as an actual control of the instructional process. But the reason I wanted you to see this is because of the economic implications. Notice that that enormous system was put in for some other purpose, and then it was used for training purposes. We're going to see this in industry more and more. Any industry, such as the hotel industry, where there is a communications network with some kinds of communications devices, and a central computer can use that computer in the training mode, even in this primitive way, and with perhaps a little more sophisticated approach with what we would call actual tutorial information. The limitations here are the devices which the people work with. There are not student consoles at every United Airline ticket counter, and they were severely limited. The machines could not say, "Your last answer was wrong, why don't you try again". The student had to compare the answer which came up with what was in the programmed text on the side, and so the device itself is going to limit this approach.

What we see happening here today at the Irvine Campus of the University of California, for instance, and in other educational institutions, is terminals being put in for non-instructional reasons. The Committee which reported recently to the President on higher education and the use of computers in higher education, suggested that the Federal Government invest something like 400 million dollars in the installation of time-sharing computer systems at the university level. Now, they were not thinking about computer assisted instruction when they said this. They were only talking about the computation, problem-solving, simulation areas, but clearly, once these devices are installed and paid for, then the use of them for CAI becomes more possible. I do not say that the Federal Government is going to invest this kind of money. But one answer to the funding problem might be where to look for already existing time-sharing computer systems. Then you can tack on CAI as an application. All of the major airlines, a lot of the major hotel networks, and other businesses, are going into this kind of training, although the system was never installed for training to begin with. The instructional use is simply overlaid later. It's something to watch in the educational setting.

Another area that I would like to touch on is one which has come up again and again in our discussions yesterday, and today concerns research and the problem of testing, which is perhaps nothing more than a research problem. I would like to refer again to the Brentwood brochure which, if they are still using it, tells you that CAI is PI. If you compare this with the published results of such things as student errors, as well as the response time required to answer questions, etc., you find that very little of what would normally be called programmed instruction has either been applied or tried at what I regard as our most advanced computer assisted instruction installation. I do not think drill and practice is a very fruitful research area, at least in looking at the results that have come out. After all, the students spend 45 minutes in the classroom listening to the teacher asking questions, going to the blackboard, doing things there. Five minutes of each student's time is spent at a teletype terminal in the closet doing drill and practice, and to concentrate on the drill and practice as the area where computer assisted instruction should be brought in is simply misplaced. If we are going to attack the instructional process, what happens in the other 45 minutes of the classroom seems to me to be the important area. Let me describe a research study that was done in the early history of programmed instruction, that I think might provide some lessons for us here.

Way, way back when people were arguing about such things as, are overt responses really necessary, and all the other issues which surrounded the programmed instruction field, a very interesting study was carried out at a major American university in which the researchers directed themselves to the very appropriate question of how important the overt response is. Another way of phrasing the question which they thought of was, suppose you just have a student read a program of instruction in which all the blanks are filled in. Would there really be any difference between his behavior and that of somebody who filled in the blanks? So they directed themselves to this model and took materials which were in the form of a program - a program in statistics I believe it was for college students - and they ran control and experimental groups through, and then gave them the test at the end, and lo and behold, there was no significant difference between those who read frames in which all of the blanks had been filled in, and those who actually were required to fill in the blanks. On the basis of these results, they concluded that overt responding was some kind of fraud which the psychologist had perpetrated on the rest of us, and that the same thing could be accomplished in other ways. These results were published and otherwise sober people repeated them, and regarded them as solid research results. The problem was, of course, that another hypothesis was possible: that the material which was used to do the testing was so like an ordinary textbook that there would not be any difference between reading it and filling in some blanks. Some people's idea of programmed instruction is that you simply take out a few key words in a paragraph, and you have the student fill those in; that makes him participate, and he learns. I do not mean to beat a dead horse here, we recognize now that this is not what is involved. The important point I'd like to bring out is that the quality of the materials you work with is important to the research. You are not discovering anything if you take a poor program and test it any number of ways. Your statistics, your correlation, you can back this up with all the correlations you want, if the materials to begin with were bad programming, nothing is proved.

I think that unfortunately the image is developing that the computer assisted instructional system somehow by-passes the programming area. You have a gigantic, powerful machine and a reference manual, telling you exactly how to use it. What is the matter with handing the teacher the reference manual and letting him go? I think that one of the problems of doing this is, that at present, it lacks the necessary richness of stating the objectiveness, setting up the stimulus sequences, calling for the proper responses, making the responses relevant to the information being tested, going through an analysis of concepts, to discriminations and generalizations, going back and forth in concept formation, making the student discriminate between the class you are trying to teach him about and all the other classes, and jumping back and forth between that and getting him to generalize within the class you're involved with. If you ignore all of these aspects, then the results of computer assisted instruction research are not going to be any better than the use of the computer to simulate what a pretty good teacher would be. I refer to the Scientific American article on the Brentwood project. Nothing was shown there which wasn't known before. Drill and practice exercises were used, but there was no overall programming approach. How the decision that drill and practice excercises are the right place to start was arrived at was not made clear. The interpretation of the data which did occur has been published on one page of the Scientific American article. There is a list of problems that were presented to the child for solution, and it was pointed out that #7, which consisted of an equation, received a lot more errors than #9, although #9 was the exact opposite of #7. This was presented as some kind of puzzle. Anyone who has been involved in behavioral technology would immediately want to suggest a sequential effect here: maybe the reason #9 was answered correctly more often than #7 was because it followed #7. This apparently did not occur to the researcher on that particular project. It's being the "exact opposite of 7", is an interesting arithmetic or logical feature of the material, but is not the point of the behavior of the student who is trying to work with this kind of material. And so I must come back to the original statement that the quality of the programmed material is of importance. The research results are not going to improve until more attention is paid to these areas, and perhaps more people with these kinds of skills are involved in the sort of work being done.

Let me proceed to my last point and then I shall stop. Here is a chart of systems components and the reason I am showing this to you is to help in identifying the various parts and functions of the many different kinds of systems that you will be seeing in the next week. We have talked about hardware and software. A pretty detailed list of what you might expect to find, and the functions that these things perform can be listed.

First of all, there are the hardware components. We have the central processor which executes the programs stored in it. We have the student terminals, and here I have a number of different components. If you are using a teletype system, you will have either a computer printer or a teletype, or some other kind of printer. A cathode ray tube display is often found. A projector indicates in the IBM 1500 system they use, I believe, either slides or strip films with random access to a 1000 frame. The functions that these particular components play is to present information, directions, and questions to the student. Then there are keyboards, and you will see these in almost all of the systems being discussed. There are light pens used only with a cathode ray tube, and some systems use microfilm so that the student's audio responses can be recorded and used in some way later on. The function of these components is to accept student responses to questions; or one of his responses may be held. It can be, "I need more assistance". It is not just a straightforward Skinnerian type of response.

Then there are input-output units of various kinds not connected with the student. When you look at the Brentwood installation, the first room you go into is full of a lot of these other devices and you will wonder what they are all there for. They are for the operator to use, and consist of on-line printers, card readers and punchers, operator-consoles, etc. In the terminology of the IBM system at Brentwood these are proctor consoles. They allow the operator to load programs and course materials, to call for print-outs and summaries, etc. and, in effect, to manage and control the system.

Then you will see boxes which contain auxilliary storage units and almost all of the manufacturers here are using disc random access devices. In yesterday's presentation, we had a fine description of what these are. They provide storage for the courses, for accumulating the statistical data, for actually storing some of the programs which are used, etc. Finally, there are switching units which control the various student terminals

Now the word software has been thrown around a lot in the last two days. I have used it here in the very strict, perhaps old-fashioned sense to mean the computer programs which perform the following functions. There has to be a program to allow the instructor to load the course material, to request performance data, and to revise or update the courses in the machine. You need a program to allow the student to identify himself and the course that he is in, to select a starting point in the course sequence (the student may tell you where he is in the course or the computer may go back to his previous history and tell him where he is in the course). You need a program which then presents messages to the student and receives his responses. You have to process those responses and choose the next message to be presented. There has to be a computer program to collect, summarize, and print out performance data -- things you might want to find out such as, "incorrect" or "correct" responses, numbers or ratios, response times. You may want to do this by student, by class, by instructor, by the item in the program, by the course that is being presented, by any way that you can select this data. You must allow the system operator to set the time-sharing limits and priorities. You have to allow systems programmers to make changes in the software itself. Now this body of programs which must be stored inside the computer before you can begin, this, I will call software, and I would like to suggest that this is a proper term.

There is a lot of other material which I call course material, to distinguish it from the software. If you call the course material software, too, then you have to make up another term to describe the computer programs. These materials are stored in the system for two purposes: for presentation to the student (you give him information, directions, and you ask him questions), and for the control of the course sequence. You have to put in the criteria for evaluating the student's responses; that is, you may store correct answers and bounce his answers off of them to see whether they are correct or not. You must have some way of specifying the rule for choosing the next message, and you may want to do this on the evaluation of the last response, the student's performance history, or whatever.

Those are some components of the kinds of systems that you will be looking at. it may help you to organize some of your comments about those systems and the way they function.

REPORT

THE LOG OF THE TRAVELING SEMINAR

Plan of the Trip

After the briefing, the panel accompanied by the Project Officer from the Office of Education and the professional staff of the Educational Policy Project began their tour. Five major research and development sites typical of sophisticated work in the field, had been chosen. This is not to suggest that the scientists and educators at these sites possess unique skills. Their work, however, does demonstrate advanced uses of the computer in education. Nor were the choices designed to present only the computer assisted instruction available today, but included as well research on particularly promising possibilities for future computer applications to a variety of educational needs.

There is a marked divergence of teaching models employed at these centers. Non-instructional computer applications to education are under investigation at some. Visits were arranged in a rough order of ascending complexity of teacher techniques. One site, of course, did not take up the same teaching approach where another stopped, rather each demonstrated research on increasingly complex teaching processes. These ranged from drill and practice methods through concept-introducing tutorial schemes (including programmed instruction without the use of machines), to Socratic strategies. Programming by students, to teach problem solving was demonstrated in the latter part of the trip, and the weeklong survey ended with a presentation of games and simulation. A considerable overlap of subject matter was involved since there is a heavy concentration in this field on mathematics and language skills. In addition to these two basic subjects instruction in the physical and social sciences were demonstrated. The group also was given the opportunity to observe an early implementation of computer assisted counseling, as well as computer programs serving administrative functions. The itinerary was as follows:

1. Institute for Mathematical Studies in the Social Sciences, Palo Alto, California

2. System Development Corporation, Santa Monica, California

3. The University of Pittsburgh Learning Research and Development Center, Pittsburgh, Pennsylvania

4. Bolt, Beranek and Newman, Inc., Cambridge, Massachusetts

5. Abt Associates, Inc., Cambridge, Massachusetts.

Three weeks later, a committee from the panel reassembled to visit:

6. The Responsive Environment Corporation's Learning Center in Brooklyn, New York
7. The New York Institute of Technology, Old Westbury, New York.

It should be noted that the sites visited included practically every type of R & D permutation and a range of profit - nonprofit structures from university to publicly held corporation. Panelists were sensitive to the effect of different financing methods on motivation, investment of risk, and management of research.

Review of Site Visits

Throughout the trip, the Seminar remained true to its name: there was constant discussion through the day at the sites which continued during the evenings and on airplanes as the group travelled from place to place. Each site visit raised further issues about the present direction and future potential of computers in education. This section will include a brief description of the group's experience at each center, along with some of the critical issues that arose in their discussions. Detailed descriptions of the research projects can be found in the references listed in the bibliography, either under the names of the researchers mentioned or of the centers visited.

1. Institute for Mathematical Studies in the Social Sciences, Stanford University.

A. Dr. Patrick Suppes met the group at Stanford, and described the basic pattern of the review drill and practice CAI being developed there in arithmetic and logic under his direction, and in reading under Dr. Richard Atkinson, using the elementary school mathematics program as the principal example.

B. The group then divided to visit demonstration centers at the Brentwood and Walter Hayes elementary schools. Brentwood provided a view of youngsters from a culturally deprived area working on arithmetic and reading review drills. Walter Hayes taps a more middle class population. In addition, its schedule includes special work in logic for unusually bright 4th grade students with introduction of concepts as well as review of classroom work.

Questions which began immediately to be debated centered on the learning process itself, and on the roles of teacher and student in relation to the machine. What can be established about how students learn, from the tracking of student scores on drill and practice problems? How will the teacher see his role in relation to "machine controlled" teaching outside his classroom - will he find the computer drill acceptable and encourage the practice it provides his class or will it be a threat? Who will produce the software demanded by such programmed instruction -- industry, universities, or present curriculum development professionals? Is programmed instruction itself the best use to make of the computer's capacities? Does drill and practice allow for other than sequential learning? Will the sheer controlling power of a computer which greets each child by name and judges his multiple-choice answers foster an attitude of submission to the machine? On the contrary, will the rational use of tools like the light pen and teletypewriter keyboard help teach the child that the computer itself is a tool, useless until it is activated by a person? These and a number of other questions about the administration of the two pilot schools provided the core of discussion during the visit to Palo Alto. This was rounded off by a brief discussion of communication futures with Dr. Wilbur Schramm, and a visit to the Stanford University Communications Study Center.

2. The System Development Corporation

The entire day was spent at S.D.C. with demonstrations provided in the conference room. Dr. Launor Carter addressed the panel first, giving a history of the organization and the range of its present activities.

A. Dr. Harry Silberman then presented a short overview of the Education and Training Division's research projects which include computer assisted vocational counseling demonstrated later in the day. He suggested to the panel three major problems CAI will face in the '70's. (1) Facilitating communications of teacher and student with the machines. The teacher does not make the programs, but if he cannot control the system effectively he will bypass it. Interface design problems are serious: young children need the opportunity to use more graphics, to write on the display mechanism and be furnished displays easily. Development of more natural languages is crucial along with programming for a broader range of responses. Ways must be devised to make English input acceptable so that the machine can engage in a remedial dialogue with the student, generating hypotheses and questions in order to teach a process of thinking. (2) Costs of implementation. The cost benefit approach will not work because it is impossible to find a fixed criterion to which to attach a dollar value. In addition, the costs will remain high because of the long time needed by many skilled people to produce software. Even hardware costs may be expected to stay high for some time because of the reliability problem. (3) Systems boundaries. Will the system in which CAI functions be the present school? There may be a need to redefine schools to cover a wider range of teaching situations for which this device is appropriate.

Discussion was highly responsive to these problems set forth by Dr. Silberman. The quality of the interface was debated: Is it appropriate to take an adult device like the typewriter keyboard because it is available and use it to teach the young. Should CRT displays remain restricted to single projections and multiple-choice presentations or can other uses be found more appropriate to the neurological processes of the young? The implementation of CAI in schools seems most likely to be made possible by prior adoption of the computer for administrative uses which are better developed. One problem here is face validity - if the administrative helpfulness of the machine is obvious, school boards are likely to buy computers. Clear value to the user is essential. This, however, raises the issue of compatability, since the hope is that the computer purchased for administration could be used for instruction. There is a critical need for equipment which can accept programs developed for different equipment. Are we presently facing an irresponsible proliferation of language and devices, or is this a necessary developmental stage? Should an effort at central control be undertaken not to standardize machinery and develop compatible languages, or would this choke off necessary divergence? Such questions are especially difficult because they involve not only technical, but also political decisions. The systems problem can become a morass. CAI can be used only for a limited time each day and should be thought of as an auxiliary to learning systems and not as the total learning environment.

B. Dr. Jules Schwartz gave an explanation of time-sharing. He noted that there are three main characteristics involved: simultaneous systems which allow multiple users on-line; general-purpose systems in which a variety of programs are possible, but usable only at different times; and independent operations where the computer can handle different programs without confusing them. While all time-sharing is not characterized by all three, CAI would require the full range of capacities. If administrative services are also to be made possible, then a dual system is needed to include batch processing for such things as running payroll at night.

C. In the afternoon, the group reassembled for Dr. Charles Frye's explanation of the PLANIT language, developed by S.D.C. for teaching statistics, but now being used for a variety of CAI and counseling functions. As described, it is easily adapted to school administration uses. PLANIT is a simple language from the user's standpoint. A program can be built by a person previously unacquainted with it who learns the language as he proceeds. Its symbols refer to natural English words, and it can be used in a shorter mode by those already familiar with it.

D. Dr. Donald Estavan and Dr. John Cogswell then discussed, and demonstrated on the computer, the company's computer assisted counseling program which at present is being tried out in a local junior high and a local high school. This uses the longer form of PLANIT (closer to natural English) and can be used by the school counselor or the student to obtain predictions about probabilities of success in college and vocational choices based on the student's I.Q. and the other test scores, previous courses and grades. The reaction of the panel was sharp, and questions tended to focus on the quality and implications of this type counseling. Correlations, for instance, between any present grades coupled with I.Q.'s and later success in a profession are built on average data. How well can this apply to one youngster who may be going through adolescent difficulties which make his grades drop and who yet has great potential? What of the effects of set on the "late bloomer" - having been "told" repeatedly by the computer that he is good for little that interests him, how likely is he to try to achieve? Would this program be better available only to the counselor to help him with record keeping and information retrieval, so freeing him for more time to discuss problems with students? He could quickly have at hand a print-out with a student's record up-to-date, including such factors as absences due to illness; he could also obtain from the computer information on the entrance requirements of various colleges and universities or the requirements and opportunities of professions and crafts.) On the contrary, is computer availability to the student a good motivating factor - is it easier for some students who would otherwise avoid the counselor, to edge into the counseling situation by starting with an impersonal machine rather than by facing an adult?

E. Dr. J. O'Toole then presented an overview of the Advanced Systems Development Division, and Dr. R. Perry described a program for the vocational education of military retirees as teachers. This is fundamentally a man-job-matching use of the computer, bringing together the need for teachers in technical skills areas with men trained in the military to those skills. The group discussed this mainly from the point of view of the social innovation involved. That is, the simple matching job in reality could set in motion a new social device to fill a present severe educational gap: the lack of vocational training teachers.

F. Dr. H. Burnaugh completed the afternoon's presentation with a brief description of BOLD (Bibliographic On-Line Display), an information retrieval system which at this time has been applied to Department of Defense technical papers. Since BOLD allows for browsing among categories of available material in the relatively simple PLANIT language, it suggests rich possibilities for massive student use of resources.

3. University of Pittsburgh Learning R & D Center

A. The day in Pittsburgh began with a visit to the Oakleaf Elementary School where non-computerized, individually programmed instruction is being used intensively as a teaching device in mathematics, languages. and the sciences. Dr. C. M. Lindvall, Dr. John O. Bolvin, and Dr. Joseph I. Lipson accompanied the group. In this school children receive not only individual programmed instruction in a subject, but small group instruction and classroom work as well. The programmed instruction includes pretests and posttests and branching where needed: to special drill for slower students, or the presentation of more difficult material for faster ones. The system is monitored by teaching assistants and the teachers rather than by machine. A child goes to a shelf for his own material for the day, checks it out with a teaching aide, and then proceeds to work. He can ask questions of the aides, and brings his work for correction when he has finished his page. At present the school is anticipating the use of a computer for record keeping, since a great deal of human time is needed to score and record. Teachers, freed by the help of their aides, go over each child's work and prescribe his next project. They can have a child go on to more difficult work alone, or assign him to a teacher or an aide for tutoring; cluster small groups of children for special sessions on material they all find difficult; and alter the general classroom presentation according to the whole class's progress. Computer tracking is being considered to offer the teacher suggestions for flexible scheduling which he can accept, reject, or modify.

This is an unusual way of using programmed instruction because it is integrated into the total teaching system under the control of a master teacher, and retains the advantages of individual rates of progression. A youngster in grade 3 may actually be reading, for example, at the 6th grade level and doing 4th grade work in the social sciences. The inevitable rigidity of preprogramming a machine for necessarily limited contingencies is avoided. This individualized instruction isolates the child less because it is coupled with the flexible, teacher-prescribed scheduling described above. In the science classes, children work with a variety of media, sitting with earphones in front of fish-tanks and bright boxes to be opened, etc., and following audio instructions to guide their investigation of phenomena. The children themselves take out their own records, put them on, and replace them on storage shelves. Further, some branching is eventually student-prescribed, a process which the children enjoy.

This use of programmed instruction, then, is not only thoroughly integrated with other forms of learning offered in the school, it is basically under continuing close teacher control and even in various ways under learner control. The demands on teachers are heavy. The program was worked out in close conference with them, and does at present take more time than their regular work day in spite of the aides who help with the programmed instruction and the clerical workers handling record keeping. The ratio of teachers to students is one teacher to 25-30 students.

Issues raised by the visit to Oakleaf clustered around the role of the teacher, as well as the learning process itself. If he indeed becomes a master teacher will this bring better qualified professionals into the field? Are the effects observed at Oakleaf transferable to other schools, or is the Hawthorne effect particularly strong here where researchers not only pay special attention to the students, but also confer frequently with teachers? Is the main benefit of programmed instruction that it allows flexible scheduling of students for tutoring and small-group sessions? Will the introduction of the computer to help in this process reduce the teacher's controlling role because of a tendency to accept the computer's "advice" as the most accurate and expert possible? When students are allowed to manage their own branching, how easily can the teacher be expected to shift his role to that of advisor? Bypassing the track system seems to be a major advance, but the Oakleaf School draws on an economically secure lower middle class population. Would it work as well with a disadvantaged group where the social class gap between master teacher and student is likely to be greater, and where encouragement of learning at home may be less?

B. The afternoon was spent at the Learning Research and Development Center, University of Pittsburgh. Dr. Robert Glaser outlined to the group the research work of the Center: on-line experimentation which allows changing variables during the course of the experiments; freestanding devices to accomplish teaching tasks without the need for the expensive power of a large computer; CAI research, including development of terminals better adapted to manipulation by children, and establishing the parameters needed for instructional decisions by computer - the kind and extent of information about a child's performance which should be stored.

C. Dr. William Ramage and Dr. James Holland then discussed research on CAI, and a tour of the laboratory followed. The uses of the computer for data collection and manipulation, and for research on CAI were presented as unique jobs which require the computer, whereas much actual instruction can then be accomplished throughout school systems by smaller, free-standing hardware. These devices should be fairly simple, and comfortable for the child to use. Prototypes of touch-sensitive input devices were shown, such as the totally sensitive CRT screen on which a child may draw with a light pen, and on which the teacher can also draw and write from his control station. A further refinement is specially sensitive paper on which the student can draw or write even with a pencil: the lines are reproduced in light on the CRT, but the student takes a copy away with him from the machine and study session.

D. Research on reading and early verbal learning was presented by Dr. Paul M. Kjeldergaard. A free-standing device is used which has audio and oral capacities, plus a window with three choice buttons. It allows individual phonics and reading drill as the child presses a button, sees a letter, and hears the sound.

E. Mrs. Lauren Resnick then described teacher training research which is aimed at discovering the crucial variables in the teaching and learning of basic skills for the pre-school child. The concept of parallel lines, and the learning of color names had been chosen for this pilot project. Teacher trainees are allowed to make only certain specific statements to the child in the attempt to separate out cognitive variables.

F. Dr. Glaser sat down with the panel at the end of the day for a general discussion about the changes CAI can bring to education. Will the tangle of "special education" classes be unravelled so that everyone is taught according to his needs? Will testing as it exists today disappear in favor of the constant feedback available from each learner's performance? A huge data base can become available. Will this allow the teacher to make individual learner prescriptions? The division of subject matter into neat categories may change radically - for instance, visual imagery in mathematics will be possible so that a child can begin to learn about calculus by watching how a point reaches its limit.

4. Bolt, Beranek, and Newman, Inc.

A. The last morning of the trip and part of the afternoon were spent at this software, service center, and engineering research corporation. Dr Bolt addressed the group first, giving a history of the organization, and its involvement with computers, languages, and instructional systems.

B. Dr. Wallace Feurzeig and Dr. John A. Swets then joined the conference. The first research project described was the Telcomp language developed to allow easy dialogue with the computer (a 6th grader can learn this Telecomp in about half an hour).

C. Demonstration followed of the student-programmed mathematics now being used in five schools in the Boston area. The instructional orientation is problem solving, rather than reinforcing the acquisition, step by step, of small bits of information. Essentially the student learns concepts by using the computer as a tool to solve mathematical problems at a teletypewriter interface. The panel was shown an example of a youngster working out the least common multiples of a group of numbers, and so discovering the algorithm involved. Children, including the average and below average are reportedly enthusiastic about the exploration this allows them. Some group problem solving develops in the classroom as the youngsters, lined up for their turn at the terminal, begin offering suggestions and making hypotheses about solutions.

D. A demonstration of the Socratic case study method followed. Solving a mystery was the example, although BB & N, in conjunction with the Harvard Medical School, is developing a program for giving fourth year medical students practice in medical diagnosis. Again, the approach is not to teach "straight facts", but to facilitate wider learning. The student uses data provided, his previous learning, and an inquiry system to form hypotheses in increasingly closer approximations of the causative situation. The program uses natural English, and a long list of possible responses is provided the student.

E. The last demonstration was of "Little School", an information retrieval system for administrative use programmed in Telecomp. It makes it possible for school personnel not experienced with computers to utilize computer files easily. (Further description of this system is not only available in the bibliographic references, but can be found in Dr. Wesley Meierhenry's chapter under his discussion of computer advantages for educational administration).

The demonstration of the mathematics program brought questions about group learning to the fore. It was suggested that we do not know the optimal balance or sequences of group vs. individual learning. Group CAI would seem to have great learning advantages, and totally isolated instruction ignores human learning needs. In addition, the problem-solving tool use of the computer helps form logical thought at the same time it reflects back more faithfully the student's cognitive style. What are the implications for teaching of variations in congitive style? Can this question be separated from the social matrix of the individual? Will it then be sufficient to try to asses a child's functioning at the terminal only, or must there be investigation of this matrix?

Material describing the work of the center in greater detail was mailed to all participants, as it was at other centers visited.

5. Abt Associates, Inc.

A. Dr. Clark C. Abt reviewed the development to the present of games and simulations and described for the seminar participants his company's use of manual games for teaching social studies. They provide a situation where the child can learn by doing - that is by problem solving, by making mistakes, by experimenting with outcomes and variables. The child can actually make history or manipulate the country's economy within the limits of the rules characteristic of that period. He is therefore offered the opportunity to learn by being presented, for example, with an historical situation and being given a role to play within a set of parameters determined by the game being played. Mr. James Hodder noted that non-computerized games in the classroom have certain limitations. The learners often need more information, and in order to get it must interrupt the game for library study. A computer could be programmed to provide more background information, on demand, and further would show consequences of a given action more quickly. But it may also be true that there is more intense interaction between players, sharpening motivation for learning, with manual games.

B. A demonstration of "Manchester" followed. Issues raised included the cooperation, as well as competition fostered by this technique. There was also discussion of the understanding of human motivation students can begin to acquire when they take up the role of a human being operating with certain (historical or economic) goals yet with a personal style, under given restrictions. If the student's own motivation to learn is sharpened by such participation and re-invention, does this have implications for teaching strategies in general and the most effective use of computers in classrooms in particular? Should active, learner-controlled work be emphasized rather than more passive programs?

6. The Responsive Environment Corporation Learning Center

Dr. John Martin, Dr. Ed Welling, and Dr. Benjamin Israel greeted the committee of panelists to observe a demonstration of individualized reading instruction by Talking Typewriter and the related small-group teaching method used for culturally deprived first grade children. The group could watch the children in their booths through one-way mirrors and discuss details of the programs with the booth attendants. Later there was an opportunity to watch the same process with older, (high school age) slow readers.

Since this instructional system is based not only on a form of programmed instruction, but on the tutorial strategies a teacher using the regular school reader might employ, questions were raised about the essential uses of the computer in instruction. What unique work can it perform? Is its best function indeed monitoring a variety of teaching devices? How much of the success of this reading project is due to bridges formed by the booth attendants who are from the same social background as the children and communicate with them much as their parents do? How critical is the time spent in the small-group classroom in integrating the booth work with the ordinary class day? How well do the public school teachers understand the Learning Center work - is one of the critical variables the integration of this work within the local public school system? How well can the system be adapted to another community?

7. New York Institute of Technology

Dr. Alexander Schure met with the committee for lunch and described the Institute's systems analytic approach to higher education. Afterwards, the group toured the campus to see the various free standing devices used in classrooms. These ranged from an Edex system to teaching machines available to students for optional review work. The Institute is also adopting on and off-campus CAI system planned to reach 4000 students. Diversification of media is considered essential to provide flexibility. The basic concept provides for devices and courses under teacher and student control with a computer system for record keeping and retrieval.

Discussion revolved around broad policy issues. Is there any point in using increasingly powerful computers for CAI? Should concentration, rather, be on more appropriate terminals and programming excellence? CAI research at this time tends to be fragmented. Among other problems, there is need for evaluation of the effective parameters necessary to improve programs. A National Educational Technology Policy Laboratory was suggested to coordinate communications between the Regional Laboratories, industry, and university research centers. Such a national laboratory would study all educational innovations, and not be restricted to CAI. The coming communications explosion will have social ramifications which must be taken into account in planning schools and in implementing CAI. Schools need to be better integrated into their communities. Planning must be done within the framework of the social, economic, and political realities of the communities served by the school.

This last meeting of members of the panel resulted in the concession that continuing and realistic monitoring of the field is necessary, so that those involved in decision making may have adequate and well formulated information, and so that a degree of order and system be integrated with the freedom of Research and Development necessary to progress.

THE PANEL

BIOGRAPHICAL DATA

Ten senior scientists and educators with a wide range of talents applicable to education and to computer technology were assembled for the Seminar. The group included two deans of education, an architect, the president of a university, 2 psychologists, a psychiatrist, a sociologist, a director of curriculum development, and an economist. They provided competence in many areas: research and development in educational media, engineering, educational research, school design, systems analysis, program development and innovation, and programmed instruction. The following is a brief professional description of each consultant. It does not, however, begin to reflect the sum of the talents represented by the Seminar.

Dr. C. Ray Carpenter: Research Professor, Psychology and Anthropology, The Pennsylvania State University Department of Psychology.

Dr. Carpenter is scholar, scientist, and humanitarian who for many years has been deeply engaged in the study of educational processes. He is presently Chairman of the Committee on Research and Development in Higher Education of the American Association for Higher Education, and Acting Chairman of the Advisory Committee on Media Programs and Research of the U.S. Office of Education. His research activities at this time include the study: "Conditions and Factors Affecting the Quality of Instructional Television Programs" for the Office of Education. Dr. Carpenter serves as consultant to numerous universities, institutes, and foundations in his fields of interest. Among these are the Yerkes Regional Private Research Center Board of Scientific Advisors, the Planning Group for a Regional Educational Laboratory in Virginia and the Carolinas, and the U.S. - Japan Cooperative Science Program. He is also editor of the international journal Behaviour. From 1952 - 58 he was Head of the Department of Psychology of Pennsylvania State University, and from 1957 - 62, Director of Academic Research and Services.

Dr. Donald A. Cook: President, Donald A. Cook, Associates, Inc.

Dr. Cook was educated at Princeton and Columbia, and received his graduate training in experimentally based learning theory at the latter institution. He has taught psychology at Barnard, Columbia, and Fairleigh Dickinson. He was formerly Director of Programming at Basic Systems, Inc., and later Manager of Technical Planning, Xerox Education Division. Dr. Cook has published extensively in programmed instruction and related fields. He has served as consultant to the Responsive Environment Corporation, and as an independent consultant in the areas of educational evaluation, planning, design, and utilization.

Dr. Frederick J. Duhl: President, Behavioral Systems, Inc.; Director of Education, Boston State Hospital; Assistant Professor of Psychiatry, Tufts University School of Medicine.

Dr. Frederick J. Duhl, M.D., is president of a consulting firm whose activities are focused on the areas of education, mental health, health, and welfare services. His formal education has been primarily in the field of his specialty, psychiatry. His orientation to the humanistic aspects of education as well as the complex interrelationships in and between organizations concerned with human development derives from his practice as a psychiatrist, as well as his interests in General Systems Theories. He is the co-editor of a forthcoming book entitled, General Systems Theories and Psychiatry, with Dr. Gray and Dr. Rizzo.

Dr. Russell P. Kropp: Director of the Institute of Human Learning and Professor of Educational Research at Florida State University.

Dr. Kropp's current research deals with the measurement of higher level mental processes, and the optimization of learning through aptitude treatment interactions. His teaching field is educational research methodology. His recent publications include: "The Construction and Validation of Tests of the Cognitive Processes" as described in the Taxonomy of Educational Objectives (U.S. Office of Education Cooperative Research Project No. 2117), and "Identification and Definition of Subject-Matter Content Variables Related to Human Aptitudes" (Office of Education Project No. 2914).

Dr. Hylan Lewis: Professor of Sociology, Brooklyn College, the City University of New York; Fellow, Metropolitan Applied Research Center, New York.

Dr. Lewis is not only a distinguished sociologist, but one with special training and practical experience in economics, labor relations, and personnel work. He is a gifted teacher, and author as well. He has consulted extensively for the Government on manpower, delinquency, the mental health of children, and problems of the aged. He served as a Chief Consultant to the 1965 White House Conference on Civil Rights, and is a member of the Head Start Research Advisory Committee. In addition, Dr. Lewis works on numerous boards and committees concerned with education, labor relations, and inner city problems. The consulting activities have given him wide experience both in the United States and abroad. He is the author of Blackways of Kent, and of many recent articles on problems of poverty and race.

Dr. Eugene McLoone: Lecturer, College of Education, and Lecturer in Economics, College of Business and Public Administration of the University of Maryland.

Dr. McLoone has worked on the economics of education and the financing of public education at the elementary, secondary, and higher education levels. His most recent publication is Long-range Revenue Projections (For State and Local Governments) written as part of the State-Local Finances Project of The George Washington University. Previously, he was employed by the U.S. Office of Education where he prepared comparative descriptions of state finance plans and school expenditures. He has served as a consultant to five states in designing state aid plans; to various school boards; to The Great City School Improvement Council; to the U.S. Commission on Civil Rights on the relationalship of state aid to large-city school finance.

Dr. Wesley C. Meierhenry: Assistant Dean of Teachers College, University of Nebraska.

Dr. Meierhenry is the President of the Department of Audiovisual Instruction of the National Education Association. He was a member of the team that recently visited Guam to develop a plan for educational improvement via the media. He was recently appointed to the Advisory Committee on New Educational Media of the Department of Health, Education and Welfare. He is consultant for the Subcommittee on Innovation and Efficiency in Education of the Committee on Economic Development, and for colleges, universities, and public school systems. Dr. Meierhenry's most recent publication edited was Media and Educational Innovation, and he has at this time two books in press.

Dr. Alexander Schure: President, New York Institute of Technology.

Dr. Schure is a pioneer in advanced educational methods, including the use of multi-media. He is the author of more than fifty publications in the electronics field, and the director of numerous research programs relating to the application of technological devices to education. Under his direction, a research program on a systems approach to education is being conducted at the Institute. Dr. Schure is a consultant to the U.S. Office of Education, the New York State Board of Regents Vocational Advisory Committee, and to the Educational System of Brevard County, Florida. His service and membership include such committees as: Chairman, Task Force, Curriculum Development, Electronic Industries Association; Director of the Council of Institutions of Higher Education of New York; Chairman, ETV Committee of the Council.

Mr. Charles B. Thomsen, A.I.A.: Associate Partner, Caudill Rowlett Scott Architect Planners, New York City.

Mr. Thomsen has been responsible for developing computer capabilities within the firm prior to his present position of co-manager of the CRS New York office. His pioneer efforts in the field of architecture led to the firm's development of an active computer research program. Mr.

Thomsen has authored several articles for professional journals and is currently writing chapters for two different books on computer applications in architecture and education. He is a former Assistant Professor of Architecture at Rice University. Mr. Thomsen serves on the national committee on Research of the American Institute of Architects.

Dr. Elizabeth Wilson: Director, Department of Supervision and Curriculum Development, Montgomery County Public Schools, Maryland.

Dr. Wilson has had extensive experience in teaching, administration, and curriculum development involving children and adults. Her own education was completed at Harvard University in educational psychology, and at the University of Maryland in philosophy and comparative education. She has worked abroad as well as in the United States: in elementary school teaching, as a Navy Information and Education Officer, and later as Education Specialist on the American Education Tour in Korea. In 1965-66, Dr. Wilson served as Project Director at The Center for the Study of Instruction of the National Education Association.

Balance is perhaps the one word which best characterizes this compleat educator whose pre-eminent concern is with the learner's needs, but who also devotes close attention to the necessary logistics of the system. He shows a calm acceptance of the computer as a tool to be used by human beings for good or ill - a device whose impact on education will force us to be precise about our goals and means in the classroom, and will allow us, if we accept the challenge of it potential, to expand startlingly our capacity to educate. He is a teacher, as well as an educator. It is all too easy to glide rapidly past his gentle phrases filled with meaning, yet he exposes with clarity major issue after issue. The paper ranges from advantages and weaknesses of present instructional programs through the dangers of mechanical reliance on the computer. It is well founded in today yet looks to tomorrow with imaginative suggestions for concept development model building in education.

COMPUTERS IN EDUCATION

Wesley C. Meierhenry

CAI and the Crisis in Educational Policy

The invention and the introduction of a new device into a society always changes the form of that society so that it never again returns to its earlier state. For example, the movement from the stone age to iron age implements brought about great societal changes. Educational institutions are similar to the societies of which they are a part inasmuch as they too change in response to new modes of doing things. Education has and will be changed more by the the introduction of computers than has been true of any other invention in its history. The writer, an educator, will examine some current applications of the computer to school systems and to the teacher education institutions which prepare practitioners for the schools, some concerns about the application of computers to education, and finally opportunities which the computer represents for the solution of some complex and knotty educational problems.

A recent report on the use of computers in colleges and universities indicated the following implications:

> "Computers were first introduced into universities as rare and special pieces of equipment used for a few specialized sorts of research by small groups of people. Today, many universities and colleges have

> centers which serve most of the students, faculty, and administration both by providing training in programming and by meeting computing needs for undergraduate education, for research, and often for administration.
>
> Where adequate computing facilities have been available, the faculty has made increasing use of computing in both research and education, and computing has become a part of more and more undergraduate courses, including business subjects, social sciences, biological and health sciences, psychology, geology and other disciplines, as well as mathematics, physics, chemistry, and engineering. This is consistent with the rapidly growing use of computing outside the schools in small as well as large business enterprises, in government operations and national defense facilities, and in almost all technology -- those many fields of endeavor where most college graduates will find their places. Computing is not an esoteric or specialized activity; it is a versatile tool useful in any work with a factual or intellectual content. Computing is becoming almost as much a part of our working life as doing arithmetic or driving a car. [1]

Because the influence of the computer is so broad and widespread on the educational enterprise, its introduction has brought into clearer focus some of the problems which were previously only vaguely visible. One such problem is that of policy making itself. The history of education in the United States has been that local school authorities have been the so-called "gate keepers" of decisions. Because of the instructional, financial, and organizational implications of the computer it is evident that all decisions can no longer be made at a local level. As a consequence, regional, state, interstate, and federal levels of planning and decision making are now recognizable. The introduction of the computer will make it necessary to re-examine and possibly to re-allocate some responsibilities to these different levels.

A second area in which the computer requires us to consider new solutions to all problems is in regard to the concept that education takes place only within the formal setting now considered a school system. The computer, because of its cost and its instructional implications, requires broader and deeper consideration of what education is all about. Education will be considered increasingly as a neighborhood or community wide experience involving not only the schools but community groups and agencies, both public and private. Such programs as Head Start and the Job Corps have indicated the untenability of considering the school systems as

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1. Computers in Higher Education. Report of the President's Science Advisory Committee. "Computers and Undergraduate Education", p.7.

the only educational institution in the community. Even for the age groups covered by the school system there are new kinds of quasi-public institutions being formed to deal with the complexities of the educational problem.

For the purposes of this paper, however, an assumption will be made that there will continue to be a school system operating a formal program somewhat as it does now. Even within the formal school system as it is organized at the present time, the use of the computer in instruction requires that learning be thought of according to a multi-dimensional model, including content, culture, and the learner. Although emphasis may be given to only one of these dimensions at a time, the programing of the computer forces the consideration of the other two and the recognization of the dynamic interrelationships among them.

Current School Tasks

Sufficient developmental and research work has been done to demonstrate the feasibility of carrying on many current school tasks via the computer. There follows a list of activities, functions, and operations for which computer programs exist which demonstrate the practicality of doing them via the computer. It is recognized, however, that in some cases the costs of performing these functions may be excessive, making it unreasonable for all schools to adopt these practices at the present time.

1. Budgeting

There are a whole series of financial operations in a school system for which the computer can be utilized. Such matters as placing orders and writing requisitions, drawing checks and vouchers, maintaining inventories of school supplies, textbooks and library books and many other similar routine tasks relating to budget control can be accomplished on the computer. It is safe to say that the most frequent use of the computer in school systems has been for matters related to the budget and that although the operations involved are important, they are probably not the most significant tasks for computers to accomplish in education.

2. Scheduling

One problem which has plagued junior and senior high school principals for decades has been scheduling. Until the advent of the computer it was necessary to perform the task of scheduling manually. In a large school the task was time consuming, and even with the greatest care it was impossible to eliminate all conflicts. With the advent of the computer it is possible for scheduling to be done within a minimum amount of time and with confidence that the conflicts which appear are impossible of solution. Many school systems are moving toward modular scheduling which permits the arranging of a new schedule each day if it is so desired. Thus the computer makes possible the individualization of instruction insofar as time allotments are significant in the individualization process.

3. Teacher Assignment

It is now possible to determine quickly the background and experience of the teaching staff in order that the best prepared teachers can be assigned to appropriate class sections. It was possible to do this previously but the task was such a laborious one that personnel offices simply found it impossible to make the required evaluations of individual teacher backgrounds. Thus the computer can assist in making assignments which are desirable ones for the teachers and for the pupils since they will have assigned to them the most appropriately trained teachers.

4. Computer Assisted Instruction

Use of the computer for instruction is being demonstrated in a number of places across the country. There are two rather different kinds of computer assisted instruction which are currently being explored. First is the presentation of content in the traditional manner or format. In such instances the computer is being used to provide drill and formal instruction in much the same manner as a classroom teacher would develop it. In addition to the presentation of the content the computer is capable of gathering large bodies of data which can enable content specialists and curriculum planners to understand the ways in which students learn content and also to develop new and better instructional sequences in new curricula.

A second way in which the computer can be used is to have the student do the programing himself by operating within parameters which have been programed into the computer. Under this type of system a student discusses a problem in the Socratic fashion with the computer. The computer provides data upon request and evaluates a proposed solution by the student indicating if it has been attempted too soon and why. It is obvious that in this kind of arrangement the student is a much more active participant in the shaping and molding of the instructional sequence.

5. Counseling

It is possible to use the computer for at least two different kinds of activities relating to the counseling process. First, the computer can be utilized to record and compile large amounts of data about an individual, making it possible for a trained counselor to evaluate this data and thus enabling the counselor to raise appropriate questions with the counselee. In the past it has been impossible to find ways and means of identifying, collecting, and summarizing the masses of data which a counselor should have about each individual with whom he was working. The computer is an effective and efficient instrument for accomplishing these tasks, thus making it possible for the counselor to utilize his time in more meaningful face to face relationships with his counselee.

A second contribution of the computer is to provide vocational information to a student who requests it from the computer. It is possible to store in the computer bank pertinent kinds of information concerning personal qualities and characteristics necessary for success in an occupational field, likely chances of success of a person who goes into the field with certain kinds of background and the personal and financial satisfactions of the field. Following the interrogation of the computer by the student the counselor should then be able to engage the student in a much more meaningful and fruitful face to face dialogue.

6. Information Storage and Retrieval

One of the most serious educational problems relates to the knowledge explosion, and the consequent ways in which knowledge is catalogued, stored and retrieved by teachers and students. The computer represents a particularly useful tool to accomplish exhaustive searches as information is sought. Therefore, the computer can be particularly useful to print-out sources and locations of bodies of knowledge related to a problem being researched. A second use of the computer is to store documents and other kinds of information so that an actual print-out of the material can be obtained upon request. The computer thus can serve both as a search instrument as well as a storage and retrieval mechanism.

7. Simulation of Innovation

A problem with innovation in education has been the difficulty of knowing in advance the impact which a new practice would have on various aspects of the educational enterprise. It is possible to program computers to monitor how such factors as the teaching staff, the students, or the budget might be influenced if a new instructional idea were adopted. It could be determined, for example, what might be expected to occur in terms of student decisions and the physical movements of the student body if a school system were changed to an individualized basis. A board of education could be informed what the impact would be of adding one more student to each class in terms of space requirements, decreased instructional costs, and other similar kinds of operational and administrative questions. Computer simulation of either bits and pieces of the school program or the examination and prediction of the impact of a new idea upon the total school organization represent high potential uses of the computer.

8. School Operations

There are a large number of day by day decisions which administrators, supervisors, and teachers have to make which should be made on the basis of data and information but which often are made intuitively and/or emotionally. The operation of Medinet in hospitals, clinics, nursing homes, doctors offices and medical laboratories in the Boston area is an example of the kinds of data and information which school systems require in order for sound decisions to be made. Medinet's goal is to enable results such as the following:

> "Much of the valuable time of doctors and nurses in today's hospitals is spent in clerical work, keeping track of patients' records, recording admissions and discharges, filing and filling out innumerable forms with the same information. In medical research laboratories, skilled technicians spend valuable hours mechnically assembling data. Precious time often is lost while a medical history is being retaken, or being obtained from a hospital in another city. Doctors can duplicate each other's efforts when they do not know that the information needed is available elsewhere, and valuable medical data often see limited use because their retrieval and analysis is too time-consuming.
>
> When operational, MEDINET services will mean: less clerical tedium in recording and routing information; faster access to patient data when and where needed; more effective dissemination of information accumulated in medical practice and research.
>
> Specifically, MEDINET service will assist hospitals to achieve these typical advantages:
>
> ### Simpler, Speedier Admission and Discharge Procedures
>
> When a patient enters a hospital, a secretary or admissions clerk puts the necessary data into the MEDINET system via a keyboard. The system makes the data immediately available to any qualified user. This instantaneous availability of the hospital census, in full detail, can lead to increased utilization of the hospital's facilities.
>
> ### Clear and Punctual Instructions on Medication
>
> When a medication order is entered, the instruction goes by direct wire to the MEDINET center, which immediately checks the record for apparent discrepancies. If, for example, the patient has a recorded sensitivity to the drug, the system issues a warning

comment. Or, if the indicated dosage exceeds that in the department's established formulary, the system asks if the overdose is intentional. If so, the system accepts the medication order and notifies the pharmacy of the intentional overdose.

Clearer and Speedier Laboratory Reports

Because MEDINET transactions are practically instantaneous, laboratory reporting procedures are speeded up. Reports can also be automatically arranged and displayed in a predetermined order, such as chronologically, or by logical groups, thus saving valuable time.

Better Control and Greater Economy in Dietary Functions

MEDINET service will be able to monitor the complete menu for an entire hospital, patient by patient, resulting in lower cost and less wastage. An accurate record of each patient's food intake can be kept and reviewed.

Retrieval of Medical Data for Research

Time and effort can be saved by entering data from research projects and patient records into the MEDINET network. Staff assistants will no longer have to search painstakingly through voluminous files for statistical samples. The data become immediately available. The findings of one doctor can be made known to others, and the data can be manipulated in a variety of fashions for analysis and study.

Improved Patient Care

MEDINET service will offer a powerful addition to the doctor's armamentarium. Properly used, it will extend his memory, his control, and his communication ability. When the MEDINET System is fully established, a doctor will be able to ask for and receive a complete or abstracted medical history on any patient who has ever been admitted to any hospital on the network.

These factors add up to fuller utilization of hospital facilities, and to an increase in professional time available for patient care." 2

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2. "This is MEDINET", pamphlet published by General Electric, Watertown, Massachusetts.

Although the tasks to be performed in education are different from those in hospitals, the processes are very much the same. Wallace Feurzeig has listed 20 questions which might be raised in a school system in a day for which the computer could give the answer. Some of the questions Feurzeig raises are as follows:

> "1. How many elementary students live in the region bounded by Clover Street, Random Road, and the city line?
>
> 2. Bus 6 is stalled. Which students ride it? Notify their homeroom teachers and tentatively change their attendance records.
>
> 3. Three rooms are needed next Wednesday for the regional debating contest. Which rooms will be available at what hours?
>
> 4. Which students are taking Honors English?
>
> 5. Did you prepare, verify, and transmit to the state board of education the information due next month for the annual statistical survey?
>
> 6. Which substitutes are available this morning? Which of these have worked the fewest number of days this year?
>
> 7. What is the geographic distribution of colleges attended by our graduates?
>
> 8. The language labs are not being fully utilized. Is it possible to reschedule just the French classes so each student would have two classes in the lab room?" [3]

Thus, the computer could assist administrators to make wise and just decisions based upon appropriate information.

9. Research

One of the most serious educational problems has been the difficulty of performing needed and useful research. A part of the problem has been the inability to gather and summarize great masses of data which are necessary in order to do meaningful education research. A quality of the computer is its ability to store, identify and summarize data making it possible to conduct and report very much more meaningful educational research.

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3. Wallace Feurzeig, "New Educational Potentials of Information Technology", unpublished manuscript, July 1966, p.6.

Teacher Education

Teacher education has a twofold role to perform which is unique to the preparation of a practitioner in education. The first is to provide the prospective teacher with the knowledge, skills, and experiences which enable him to become an acceptable practitioner. A related but somewhat different problem is to help the practitioner learn to utilize appropriate devices and materials as a part of his own teaching. It should be determined how the computer might be used to present necessary content from the field of teacher education and also to help prospective teachers to understand the use of the computer both directly and with the students that he will eventually be teaching. It is proposed that one of the best ways of fulfilling the second objective is to have the prospective teacher make use of the technology as a part of his own preparation so that he in turn may understand the significance of that technology when he uses it with his own students.

1. Case Studies (Socratic System)

The case study approach used in colleges of business administration, legal education, and medical education seem particularly applicable to the field of teacher education. It would appear that case studies being developed in medical education, for example, could serve as models for development of case studies in teacher education. The teacher often performs as a clinician similar to the physician in the gathering of pertinent information to make a diagnosis followed by a prescription. A wide range of case studies could be programed all the way from normal or average students to all types of students with various kinds of deviating behavior. Case studies emphasize inductive rather than deductive reasoning which has been the traditional approach of teacher education and of teachers in schools. Some specialists believe that a major weakness in teaching and in education has been the almost complete reliance upon the deductive rather than the inductive approach. The use of case studies would be one way of forcing the inductive approach.

2. Student Programing

In addition to case studies utilizing the Socratic approach it would be desirable to develop teacher education programs in which the parameters of certain kinds of educational and learning problems could be determined, yet provide the neophyte teacher with the opportunity of interacting with the computer in the solution of the problem. It would be hoped that teacher education could become a highly creative and individualistic process as a result of the students being provided with many opportunities to interact with a wide variety of problem situations presented by the computer. Students preparing to teach should be required to undergo many such experiences in order that they could develop creative and innovative approaches to the solution of learning problems of their students.

3. Systems Developments

Familiarity with the use of computers will require prospective teachers to become acquainted with the concept of instructional systems. In the past very little attention has been given to helping the prospective teachers to conceptualize instructional processes, identify relevant elements that makeup instructional situations and then plan and execute in order that learning might take place. The use of the computer will compel all who work in teacher education to give attention to the total educational system and then to become familiar with the ways of breaking down the total system into its various parts or sub-systems. Such activities will also require increased attention by given to objectives and purposes stated in behavioral terms in teacher education.

4. Simulation

Computers will make possible a number of types of simulation procedures. It will be possible, for example, to model a classroom situtation and, depending upon the decisions which a prospective teacher makes, to present the likely results of her decision. If, for example, one is attempting to help the teacher to understand the pupil control problem it will be possible to present a disciplinary situation in which the prospective teacher is required to take certain kinds of actions. Depending upon the action she takes, whether it is to restrain the students, overlook their misbehavior, or try to make certain kinds of positive suggestions, the computer can display subsequent situations which will likely occur as a result of the decision. Use of the computer for simulation will enable the prospective teacher to have a great deal of practice in solving situations where she can make mistakes but where there will not be serious implications since the "students" are not real. The prospective teacher should have sufficient simulated practice so that when she begins to work with a live student she will intuitively arrive at workable decisions in much the same way as the physician does when he reviews a body of information and diagnoses what ails a patient.

5. Teacher Placement

It has never been possible to gather the data necessary to make careful judgments about the selection and assignment of new teachers. It will be possible to have on the computer all types of personal and professional data about prospective teachers along with test and other evaluation data which come from case studies, simulation work, and other teacher preparation activities. All such information summarized and made available to prospective employers will make it possible to identify in a much more effective manner the appointment of teachers with the needed competencies in order to serve successfully in certain teaching assignments. The computer could identify and summarize all kinds of pertinent information upon the request of an employing official.

6. In-service Training

One grave problem in all professional fields today is how practitioners are to be kept up-to-date in terms of new content, methods and practices. Teachers are not exceptions to this rule and the additional problem is that there are more teachers than there are practitioners in any other professional field. The massiveness of the in-service task would tax all of the ways and avenues of meeting this particular problem. It has been demonstrated that the computer can provide in-service training for teachers by presenting content in the very same way in which it is presented to the students. Because of the likely interconnections of all of the school systems within a state and the probable interconnections among the states it will be possible for teachers to carry-on in-service work within their own homes via the computer.

7. Research on Teacher Training and Selection

If research has been lacking at the elementary and secondary levels it is absent to even a greater degree at the higher education level, including teacher education. Very little evidence is available as to what kinds of individuals make the best teachers, the types of preparation which lead to the best kinds of practitioners, the various levels at which experiences should be given, how academic and content areas should be interwoven and how much practical experience is necessary. By monitoring and collecting large masses of data about students and the preparation programs in which they engage, it should be possible to begin to make decisions based upon facts and information.

Some Concerns

Technological developments are neutral in terms of whether their impact upon the human being is good or bad. The computer may have ill effect or a good effect, depending upon the uses which are made of it. It takes deliberate planning in order to assure the most favorable human results. In the section which follows a number of concerns are raised about the computer and whether it will be used to serve needs or whether human needs will give way to serving the computer.

1. Human Elements.

Every technological development has the possibility of dehumanizing the learning process. There appears to be a particular danger in the case of computers, however, that they might be used in such a way as to minimize human developments and interactions. Some persons, such as McLuhan might argue that the world is different as a result of technological developments and it is the educator's responsibility to be alert to the new kind of world and to learn to fit it. Others would argue that it is a different kind of world but that we must find the ways of making technology meet and serve human needs.

There are many questions which arise as one observes children working on computer terminals at the present time. For example, does it make good sense for the computer to reply back to John, a student, when he begins working on a program. "Hi, John. How are you today?" Does the child come to associate some human quality with a computer which greets him in such a fashion? The writer observed children actually raising their hand in greeting to the computer terminal when it printed, "Hi." How human is it for a cathode ray display screen to show a cartoon of a smiling face when a correct response is made? The isolation which many computer terminals require of the student may reinforce and develop even further the kind of alienation which is so characteristic of young people today. There is a question, therefore, as to whether the computer with all of its humanlike capabilities may develop a generation of children to perform as robots.

2. Invasion of Privacy

Several references have been made to the fact that the computer is able to remember and recall everything which an individual has done. There are a number of problems which grow out of the ability of the computer to recapitulate all kinds of information. For example, should it be remembered for all time and known to everyone who might ask the computer that there was a major or minor transgression on the part of an individual? Our society has generally operated on the assumption that one is judged on the basis of his present performance and behavior, and not upon some incident or group of incidents which may have occurred some time ago. Teachers, counselors, and employing officials might act quite differently toward individuals if they knew every improper act of an individual. There is evidence that an individual is likely to behave in the way in which he is expected to behave. If the student's past were an open book available for anyone to see and examine, what others expect of him, and thus his own expectations might be altered for the worse.

Because of the memory of the computer and the possible interchange of all kinds of information among government, business, quasi-governmental, or public bodies very different decisions might be made about people in the future than have been made in the past. The possibility of "big uncle" always looking over one's shoulder whether it be the F.B.I., the tax collector or the school counselor could produce a very different society.

3. Interface

It is evident that the interface (the display media and controls with which the student is in direct contact) has been determined up until the present time by the capabilities of the technology and not the needs of the human beings. Unless there is much more active participation by teachers, counselors, and psychologists in the design of the technology, it will continue to reflect the requirements considered desirable by engineers. It is questionable, for example, that a typewriter terminal is the best interface mechanism for a six year old child.

There are at least three elements of the interface problem which need attention: the stimulus, the response, and the feedback mechanism. Because so very much of human interaction is oral or written language, the relationship of the human being to the computer is not likely to be a meaningful and satisfying one until it is possible to utilize both written and spoken language for all three purposes of stimulus, response and feedback. Audio capabilities seem particularly important at the present time since the spoken word has a warmth and intimacy which the printed word does not. All children, but particularly those who come from various kinds of disadvantaged backgrounds, are likely to require oral dialogue.

If the computer is to fulfill the expectations for it, it will be necessary to perfect a much larger number of stimuli and response possibilities than is the case at the present time. There is need for the development of graphic displays to be drawn by the student and in turn reproduced by the computer along with many kinds of manipulative possibilities. The computer seems to offer a wide choice of alternative presentations, but there is danger, since it is simpler to have a narrow range of stimulus and response possibilities that engineers will not develop other modes.

4. Individual or Group

In the past most formal education has taken place in a group situation. The computer now makes it possible to move toward a completely individualized kind of education. A possible danger is that a completely individualized approach to education will be encouraged, not recognizing that many decisions in our society are now small group decisions. Decisions varying all the way from corporate ones made by a board of directors to decisions that are made by a neighborhood or community group are arrived at through group interactions. Therefore, it would seem essential that consistent attention be given to the development of display mechanisms which provide for group activities along with opportunities for individual development.

5. Who is To Produce and Distribute?

It is unlikely that classroom teachers or school systems will be capable of preparing computer programs anymore than they have been able to write textbooks in the past. One of the great voids at the present time in computer assisted instruction is the lack of software. A basic question, therefore, is who will write, produce and distribute the materials and how will the costs be met? Will the Federal Government assist by contracting with local school systems or will programs be prepared under federal contract by private companies? Where will the expertise be found for the production of program? In the business and military fields new types of specialists developed who became sophisticated in the area of computers. In education we seem to lack individuals who are prepared to fulfill such newer roles. A basic question, therefore, is whether the programs will be produced by outside agencies which might not be in close contact with education and unaware of educational needs, or will they be developed by the educators with some outside assistance, but with a mechanism for the exchange of computer programs.

6. Systems

It seems evident that the systems approach has had a salutory effect upon the development of instructional programs and materials. There is a question, however, as to whether a rigid instructional system best serves the needs of students and teachers. Therefore, it will be necessary to continue to conduct careful evaluations and research of developing instructional systems in order to determine whether they can be developed and implemented successfully.

As instructional systems are developed it will be necessary to discover also what subjects, what grade levels and what kinds of learners seem to profit most from computer assisted instruction. At the present time there seems to be limited evidence as to exactly where and how the best applications of the computer can be made to instruction. Some educators believe that the best applications will be at the pre-school level, while others suggest that the most favorable applications will be at the collegeand/or adult levels. It may be that computer assisted instruction will be found to be applicable at all levels with all kinds of learners in all content areas, but much greater research needs to be conducted before decisions are made involving such large scale implications.

7. Computer Language Problems

A great deal of progress is being made in the development of various kinds of computer languages which facilitate communication with the computer. The traditional computer languages of Cobol and Fortran were developed for scientists and engineers and thus are most applicable to content in those fields. Thoroughly satisfactory answers to the problem will not be obtained until it is possible for an individual to communicate with the computer in his own natural language. The danger is that a decision might be made to settle for something less than natural language. Decisions on this matter must not be made by the manufacturers of the equipment or the engineers who service it, but rather by the users of it.

Opportunities

Use of the computer in education will enable us to solve a wide range of problems which currently are difficult or impossible to solve. Although the technology is not now available to help us do some of the things which are discussed in the following section, it is obvious that only time stands in the way of the necessary inventions.

1. To Project and Validate New Teaching and Counseling Models

The most distressing aspect about the use of computers in education at the present time is the inability of the computer to project new models of teaching, of counseling, or of organizing education and to determine the effectiveness and efficiency of such new models. Almost without exception all of the computer applications at the present time utilize extant models of teaching, counseling, or administering. It makes no difference whether one is considering the development of mathematics programs by Suppes, the counseling programs by the System Development Corporation or case studies used by the Harvard School of Business, they are each based upon what is considered to be the best approaches of expert teachers.

One of the reasons why this is so particularly upsetting and galling to the writer is that schools and teacher education institutions have been under severe criticism for not developing more effective and efficient educational models. It is interesting, therefore, to see persons coming from outside the field of education who have frequently been critical of education but who are unable themselves to project, try out and validate new teaching models. Instead they fall back on the exact same models which have been considered obsolete.

An area of very great promise, therefore, is to use the computer to project entirely new educational models of one kind or another. These new models would be projected by the computer as it examined traditional models and analyzed results in such a way that it would project better solutions to the problems. Among the solutions which it might help us to stimulate and develop would be the role of the human teacher in schools of the future. What is the best use of human resources? Is it the giving of information and other routine tasks which have been generally performed by the professional in schools, or will it be as a counselor and guide to the individual student? Are there, in fact, totally new and different kinds of roles which the professional teacher should perform which have not even been identified or explored at the present time.

2. To Gain Insights into Learners

There has been a great deal of discussion of such problems as cognitive styles on the part of learners. Are there such styles, and are they the result of heredity or environment? Is it possible to make up for certain deficiencies of a learner through various kinds of educational experiences? It would be hoped, that the computer can be used to give us a great deal of information about human abilities and capacities and the extent to which they can be developed by appropriate kinds of experiences.

3. The Study of Learning

There has been a good deal of discussion of whether or not each content or discipline field has its own basic structure and whether there are unique ways in which this structure and content can be communicated to the learner. We know little about making scope and sequence decisions in a subject matter field. Suppes has pointed out that even in mathematics where it would seem that scope and sequence is a fairly clear-cut matter it is not yet known whether a problem in division such as 2 divided by 2 is a simpler operation than 4 divided by 2. Furthermore, we do not know whether certain kinds of operations have to be mastered at certain ages or grade levels, or whether they are picked up somehow without formal instruction and applied at a later age. Some of the work underway at the present time will help to answer questions about the learning of content including the ways, the means, and the timing of the teaching.

4. The Matter of Individualization

The present movement in education is toward complete individualization. Whether individualization is necessary or even desirable is a question to which we do not have the answer at the present time because we have never had the means of really individualizing teaching. Cronbach has raised a question as to whether or not individualization is an attainable goal and even if it is, whether it is efficient and economical to attain it. It should become possible, as a result of information collected and summarized by the computer to determine how much of the school program should be group instruction and how much should be individual.

5. New Learning Experiences

We have only begun to utilize such new teaching techniques such as simulation, the Socratic method and gaming procedures. These new experiences would seem to be both highly motivating as well as stimulating learning procedures. The fact is, however, that we have limited evidence at the present time that some of these newer approaches are more efficient and effective in terms of learning than some of the older but more direct ways of teaching. Because a computer makes possible a valid tryout of such methods, it should be possible for us to determine whether such learning innovations are desirable and if so, at what points, with what kinds of content, and with what kinds of learners.

6. Network Interconnections

One of the ways in which the use of computers can become feasible economically is through various sharing schemes. An example of what can be done within a state is Project Update in the State of Iowa. Project Update provides for each school system to be tied in with a unit at a regional level in the state which in turn has certain interconnections with a central laboratory in Iowa. In the field of medical education there is a national system operating for the interchange of various kinds of documents and information among the medical colleges. Several attempts to do something similar in the field of higher education have been made through an organization called EDUCOM. Within the next several years it should be possible for schools within a state to obtain pertinent data and information from their State Department of Education, from universities and colleges or from other sources which might have answers to questions. In addition to regional and national interconnections, there is reason to believe that satellite transmission will be a reality before too long, and certain of the channels on the satellites likely will be reserved for educational purposes making it possible for computers to talk to computers as well as to humans in different parts of the United States as well as in different parts of the world.

7. Research

Educational research will loom large in the future because momentum from increased computer use will result in great amounts of data to be collected locally and from school systems across the country. Because these systems will be interconnected it will be possible to gain all kinds of answers to questions which are simply unanswerable at the present time.

Conclusions

It is evident that many of the things for which computers are being used at the present time can be done in alternate ways at very much lesser costs. It would be hoped, therefore, that institutions and industries will continue to demonstrate the feasibility and practicability of solving many current instructional problems through procedures and devices which are much less costly than the use of computers. It is recognized that much of the research now underway must begin at the level at which it is now operating in order to move to more complex and sophisticated levels. It would be hoped that the Federal Government would not support new projects which simply replicate what is now going on, or replicate what good teachers with minimum investments in materials and equipment are now doing, but explore new areas and uses of the computer in education.

It is desirable to continue to enable visitors to visit computer activities now serving as demonstration centers. The purpose should not be to demonstrate that the centers as they are now operating have solved the major educational problems. The purpose of the demonstration centers should be to familiarize educators with the problems that are faced by such operations and to suggest better ways of solving the problems. It would be hoped that those who visit demonstration centers would return to their home situations to develop and create new kinds of operations which will move us ahead of where we are at the present time.

There is continuing need for large sums of money to be invested in research activities of a wide range of computer activities in education. Only by moving through fairly elementary and simple stages will it be possible to move to much more complex and sophisticated kinds of studies. There will be many false starts and some failures, but such unproductive efforts should not deter the Federal Government and foundations from making continuing major investments in discovering and perfecting the highest levels of use of computers in education.

C. R. Carpenter is one of the elder statesmen in the behavioral sciences and in the application of technology to education. Only his fantastic schedule, matched by his broad ranging interests and capacity, belie the adjective "elder". Dr. Carpenter, in applying his wisdom to the future of CAI, offers perspective needed by this fast growing field. It is based on educational, psychological, and technological considerations and includes the hardware-software disparity, and CAI in research and classroom use as well as in library and counseling functions. His paper considers the position of the computer in educational technology and in the educational system as a whole, and derives potential applications and problems therefrom. His views point directly to some of the decisions that must be made in the near future and to others implicit in the extended future of education as it will be effected by the new technology.

COMPUTER REGULATED LEARNING: OBSERVATIONS AND SUGGESTIONS

C. R. Carpenter

My interest in computer arrangements for providing conditions favorable in learning extends from the early 1950's to the present. The first engagement was in planning and constructing a prototype model of a classroom communicator for providing conditions theoretically favorable for complex learning. The prototype had banks of relays which processed limited information from student responses to stimulus materials presented by films. The communicator made the results quickly available to groups of forty students and the instructor through a control console. Computers were not available at that time for application to the learning behavior of individuals in groups.

Efforts were made later to design and construct response systems including "feedback" to the instructor and students in college courses that were taught over closed circuit television systems. Practical arrangements were developed for both the instructor and the students, who were distributed in up to fourteen classrooms, for initiating questions and answers. These efforts led to attempts to develop and produce courses of instruction in English and algebra using linear programming techniques with controlled step-by-step pacing for presentation of stimulus materials to groups. In this work the needs became evident for the very high speed acceptance and processing of large amounts of digital information. The requirements for computers became clear both for research and the administration of programmed instructional materials, and especially for providing rapid "feedback" and "knowledge of the results" of efforts to learn by students.

During the early 1960's, intensive explorations were undertaken, furthermore, into the area of designing a unique experimental college within the Pennsylvania State University. The core equipment of the experimental college was to be a computer linked with networks of information for and about students. After general plans had been developed, neither the computer firm (IBM) nor the University was prepared to make the financial nor program committments that were required to put the plans into effect.

A nationwide feasibility and operational planning project was conducted in 1962 with the purpose being to establish regional educational research centers. The planned emphasis was on media of instruction including computers. During this feasibility study, advanced thinkers in the field were asked to prepare statements of their judgments about the needs for broadened and sustained research on learning, and about major approached and problems for research on instructional problems. The computer as a means of processing data was generally assumed and accepted, but the computer was only rarely thought of, at that time, as a component of a large family of media and materials for regulating and assisting learners to learn. In their statement, Richard C. Atkinson and Patrick Suppes of Stanford University, included the following summary statement:

> "We propose that a research laboratory be established for the quantitative study of higher learning processes. In recent years advances in learning theory have indicated the feasibility of developing mathematical models of the teaching process. In terms of such models one can derive in an exact fashion schedules and methods for presenting instructional materials that optimize the efficiency of the learning process. The major focus of the laboratory would be to investigate the increased efficiency in learning that can be obtained by specifying optimal instructional programs for individual students. At the present time, there are a number of general ideas we consider both significant and practical to invesigate within this general framework. They are as follows: the learning of elementary mathematical concepts by school-age children; research on problems involved in teaching students how to do mathematical proofs; research on the acquisition of reading skills in young children; and the acquisition of a second language. In order to conduct research on optimal programming methods, it would be necessary to construct a computer-based classroom facility that would give the experimenter high-speed flexibility in scheduling auditory and visual information and in recording responses and latencies for individual subjects."

One of the proposed centers was to be focused on the development of computer based regulation of learning.

It was against this background of only peripheral involvements in development of computer applications as such for instruction that I accepted the opportunities offered by the U. S. O. E. - George Washington University to make further observations on computer regulated instruction.

I am not a computer expert nor am I deeply involved in computer technology. It should be possible, therefore, for me to make some observations and suggestions with considerable objectivity even though they will be made with less than complete information and knowledge.

The problem of this report is to observe actual developments of uses of computers of various kinds in attempts to provide conditions favorable for complex learning, to make judgments about potential uses which might best be served by computers, and to make some critically but constructive statements which may be helpful to those who plan and support future developments in the area of computer regulated instruction.

My background, interests and responsibilities operate to orient and select information that is related to human learning generally and to academic learning especially, and not to the solution of practical school problems. There is always and everywhere the problems of the logistics, strategies and tactics of education. There is the persistant challenge for securing, organizing and directing the resources of the materials and people needed by expanding educational enterprises both formal and informal, public and private, governmental and industrial.

The further intent of this report is restrictive: I do not propose to attempt to deal with the technical details of computers nor do I intend to review once again the standard operations and uses of computers, nor to cover topics already adequately treated in this report.

The concept of systems of equipment and instrumentation consisting of elements and components that are used together in a purposeful manner to serve clusters of related functions has become a central concept in the instructional media field. Specific applications of general systems theory are proving to be most helpful in solving complex problems of strategies of education. For some of us it has become illogical to attempt to solve educational strategy problems in terms of one medium such as, for example, the film, or television, or teaching machines, or language laboratories, even though some media approach the state of being systems. The systems view of media would hold that the digital computer, with what ever performance characteristics, is yet another important component of a larger assemblage of instrumentation needed to implementing conditions that are favorable for learning.

By contrast, the views and opinions are rejected of involved enthusiasts and the sales arguments of the computer educational industries which hold that the computer alone will solve central problems of education. The computer will be linked, I will argue, with other compatible media and modes of communication which compose an integral family of instrumentation. This family may then be used to provide varied, cohesive and effective stimulus-response conditions for human learning.

It would appear that the computer component of the family of instructional instrumentation would serve most appropriately and efficiently the functions of timing, phasing, and patterning the exposures and displays of instructional stimulation. The computer components, also, may provide what is often lacking in mediated instruction, namely, rapid and precisely timed reinforcement of learning, when responses are correct, or extinction when incorrect responses are made.

In the recent past, various media have been promoted as the single great solution to critical educational problems. The proposals and the estimates of results have usually been made by people with strong vested interests, or by educators who are over enthusiastic and hopeful.

There are those who would propose that the computer will provide the answer to the central educational problems of today. It can be used, for example, for adapting instruction to meet the idealized requirements for individualized instruction. The past history of media research and the observations made during the George Washington University's Flying Seminar support the view that the computer surely provides an important new component which principally serves regulatory functions of instruction. The computer is not, I would argue, the monolithic solution to the main problems of education. A question is: What is the correct role of the computer?

The expression computer regulated learning is proposed as an alternative expression to "computer assisted instruction" or "computer based instruction." The main computer functions appear to be regulatory. The ranges of timing, phasing, and switching possibilities made actual by computers may be one set of performances of major importance in arranging for the most favorable conditions for learning.

The bases for learning are many and not single; the learner, the stimulus conditions, the content, the media and modes of stimulus information, and pervasively, the phasing of events in the learning environment.

To define the computer as a regulatory component of a hypothetical system for solving multiphasic complex educational problems is not to depricate its importance as a component of instrument systems. The proposal is that the place and role, the functional definition, be realistically and honestly specified for the computer just as this is necessary for other components of the family of media of the educational technological system.

All reports and observations during the flying seminar on computers, reinforced or confirmed my conviction about the great imbalance or disparity between equipment development and program development. The equipment program imbalance is examplified by the pertaining situations in the Palo Alto-Stanford area. There are two International Business Machine installations and one Radio Corporation of America computer installation available to the research and development projects now being directed by Professor Patrick Suppes. The equipment is most specialized and highly developed at the Brentwood School installation. The latest advanced type of computer, the IBM 360 series, is available on a shared time basis on the campus at Stanford. On University Avenue, RCA has made available another installation.

Apparently the development of instructional programs even on the "drill and practice" level of operation in the content area of logic and mathematics is very slow and difficult work. It seems, also that staffing of programming development efforts has not been brought in balance with the very large available equipment capabilities. This imbalance seems to be a general case, for much the same condition prevails at the System Development Corporation, Santa Monica, California, and perhaps elsewhere.

What is needed, I propose, is an adequate strategy of nationwide scope for establishing and maintaining balanced efforts for instructional program development and for equipment development. The dimensions of the national needs and demands for programs might be ascertained and charted as a first step in the proposed broad strategy. Furthermore, this problem is general with educational and instructional media and need for computer "software" is only one special case. These assessments should include analysis of needs for programs for other display media such as films, tapes, radio, television, carrells, and display-regulatory machines. Here, once again, the need is evident to develop perspectives which include a range of instructional alternatives of both equipment and program instructional materials. Designing patterns of these around interrelated or interactional functions and important educational needs would seem to be a challenging first order of business.

This done, then selections of patterns of media, modes of communication and implementing equipment could proceed relative to the requirements of defined instructional training tasks and situations.

Although the logic here proposed is sound and actually widely accepted, nevertheless the terminal equipment problem needs continuing emphasis. The problem of composing assemblies of display-response equipment relative to a specific instructional learning task requirement is usually solved in an ad hoc manner without generalizable logic.

The learning cycle (or spiral) is one possible frame of reference or model for judging what phases of the cycle should have the benefit of computer functions and what phases of the cycle should be served by other media. The Responsive Environment Method uses sound tape and sound signals for switching functions. Here the typewriter (and print) is the supplemented mechanism. Even though sound tape has proven to be most useful, and serves functions of switching (as examplified by the EDEX equipment of Dage-Ratheon) similar to computers, its use remains rather limited.

The work on computer regulated instruction at The Pennsylvania State University uses a slide projector and sound tape reproducer at the terminal which provide modes for information to supplement the typewriter. Motion picture cartridges could be included also in terminal assemblies.

All of these suggestions and possibilities relate to the display functions associated with stimulus materials. Display functions merge with the covert perceptual-cognitive-selective functions of the learning cycle which intervene prior to the overt responsive phase. Immediately following the response phase and resulting possible "inputs" of information, the functions of the computer may be used to provide "feedback" to the learner. Thus, the assessment of correctness or incorrectness of trial learning responses can be appropriately timed and compared, and used in the next reiterative learning cycle. Simultaneously, information about the performance of individuals can be collected and stored for various uses.

To generalize, it now is clear that computers can regulate the timing, duration and kind of displays of stimulus materials for learning. The computer can accept data on trial learning responses, and assist the learner in their assessment. The progression can then be routed over alternative pathways depending on the developing competencies of the learner ("branching"). Records can be kept of all relevant operations and used as a basis for regulative control.

Two crucial questions are raised: 1. For what functions are computers essential or for what functions can other means be used with equal or better quality of effect and with economic advantage? 2. Is it necessary for computers through their remote on-line terminals always to serve only individual learners?

There are functions, both general and specific, which computers may serve with apparent advantage. For this discussion the questions of uniqueness and necessity of the computer are waived for the present.

Computers may be used in the research and development work of preparing and testing instructional materials. In the emerging empirical methods producing and testing instructional materials for a wide range of kinds of media, subject content areas and learners, computers may be used advantageously.

The empirical method requires that instructional units, steps, and sequences be prepared and tested with samples of target populations of learners. The work of preparing trial versions of instructional units includes the steps of testing them on samples of subjects, of collecting and analyzing results, of revision and redrafting the materials, and then repeating the cycle if the results are substandard. The empirical method can be applied so that standards of performances of instructional materials can be assured and predicted. For this work the required functions may well be served by general and special purpose computers.

The general concept here proposed is that the computer be used in the developmental work on instructional materials to achieve demonstrable quality as judged by student performances. Afterwards, the materials can be carried and distributed by media other than those that are bound to the computer. Test and measurement work can continue by both on-line connections with a computer and by other means of transmission. Also, when the instructional materials need revisions and improvements or adaptations, the computer may again be brought into play in the same manner as during original production. This use would minimize demands on computer capabilities. It would lead to materials of quality that can be distributed and made accessible to learners more vividly, effectively, and economically by media other than the computer. It seems probable that as instructional production centers and modules are created throughout the country, computer facilities and services will be necessary for them.

It is well established that teaching-learning-testing are interconnected sets of processes. The words could be changed to stimulus material-display-response-assessment and "feedback". Now then, as demands on educational systems and institutions increase, instead of developing the full sets of conditions known to be necessary for academic learning, many assessment testing functions are being eliminated. The testing operations are omitted or reduced. The computer could aid with the testing requirements if proper terminals and student response-imput stations could be developed and used. Punched cards and mark-sensing interfaces which are integral with computers and are now available could be used advantageously and extensively.

A problem of basic importance is that of providing for the optimum timing of information about a student's performances after the responses are made, either as a trial response for learning or as a test response for the assessment of achievement. The computer can aid in the theoretical and practical solutions of optimum timing of feedback to the learners. A teaching-testing auditorium or large classroom perhaps seating up to five hundred students with responders provided for each student, and those in turn connected with a special purpose computer would provide a needed means for both providing improved conditions for learning and for rapid, effective integral testing of large numbers of students. Conceivably every school, college, and university in the nation could have the technology for direct or interfaced inputs to computers to serve the escalating demands for more and better testing programs.

Classes grow larger in spite of the ubiquitous emphasis (especially when computer regulated learning technologies are employed) on individualized instructions, branching in patterns of content alternatives, and individualized rates and progression. Enrollments in basic college courses require multi-section scheduling. Often different sections are taught, and student achievement evaluated, by different teachers. There is a clearly evident need for new technologies for instructing and managing large classes and the multi-section courses. The special purpose computer with a capacity for large numbers of inputs from student response stations will surely have a place in this new technology. As more and more buildings like the Forum Building at Pennsylvania State University are built, the fairly well developed technologies for displaying information will need to be supplemented by pre-programmed display regulators, student responders, and other classroom event sensors. Provisions will be needed for processing, storing, and comparing information. This is one area where developments in equipment are urgently needed before computers can be applied to the problem.

Another major use for computers is becoming evident as the uses of various kinds of telecommunications increase and as there is the realization that active responses and "knowledge-of-results" of learning efforts are advantageous for learning. In addition, the growth of demands that mediated instructional programs be evaluated will increase the demands for appropriate instrumentation. Television and radio programs that can be designed and produced may employ punched card and integral sound or side-band signals to reinforce learning from programs received over television receivers in homes. The cards can be mailed to administrative centers and processed by standard sorters.

Computer linkages may be developed with closed-circuit instructional television in institutions or in public school systems. There would seem to be promising possibilities for developing computer regulation of carrel and language laboratory instructional programs.

Perhaps no other area of computer uses has been so extensively discussed as that of applications to library functions. Generally it seems that progress has been disappointingly slow. When consideration is not limited to computer regulated instruction but made inclusive of other media of instruction, then an important computer use could be the search of files and finding of units of materials that are needed in instructional programs. Existing films, video tape programs, slides, transparencies, and photographs as well as print materials could be appropriately fitted into programs of instruction. Libraries of instructional resource materials could be assembled and catalogued for computer search and finding of specific needed materials.

The vast amounts of existing instructional materials, especially in forms other than print, can only be made actually available after collection, clearing of rights, cataloguing, and the use of computer search and retrieval capabilities.

The uses of the computer for assisting in counseling was described to members of the Project. The equipment and programming possibilities seem to be clear. Computers make it possible to store in accumulating files vast amounts of information as it is collected on the characteristics of individual students and their scholastic achievements and inadequacies. The uses of computers for these purposes were built into the plans for Florida Atlantic University and for the computer based experimental school that was alluded to earlier in this report.

A barrier to this development appears to be that of acceptance of computer based counseling. The objections that are raised are those of the possible breach of privacy and confidence, and the belief that counseling information should be given to students personally. As is the case with medical records, there are some counseling problems that require personal interactions of students with counselors. There are other areas, however, where perhaps with limited training students can advantageously query the computer for information about himself without the intervention of a counselor. For students the selection of courses, the charting of career plans should depend more than is currently the case on objectively assessed abilities, skills and competencies. When information about this is collected, assessed and interpreted it would seem entirely desirable to provide for direct student access.

Information about jobs and positions and their requirements can be stored in computers. Furthermore, the characteristics of students and their strengths and weaknesses can be compared using computers with the performance requirements of jobs, roles and professions. It is possible that the impersonality of the computer information system may be an advantage for some kinds of counseling over the personal interview; students may have less resistance to making inquiries of computer terminals than to arranging interviews with counselors and teachers.

The final section of this report deals with some criticisms of computer developments and the retarded developments of some phases of the enterprise.

From the point of view of computer regulated learning the terminal is of first importance. Educational developments especially during the last two decades have stressed the introduction of many kinds of media and modes in addition to print for stimulating learning. The computer typewriter terminal reverts to print as the principal medium of instruction. The arrangement where sound tape accompanies the typewriter is an interesting exception. The various graphic display screens now being developed and that are under computer control are essentially electronic writing and line display on tubes or other surfaces. The modes of display are rather limited. The light pencil is not an instrument with which writing can be done. The pencil is miss-named.

In reality it is a selection pointer for identification responses and a selector for an item from sets of items and in objective tests.

These criticisms can be met in part by other media being linked into the computer terminal. Sound and video tape machines, cartridges, slides in color, motion picture projectors and transparencies, all these can be connected with or be parts of terminals and their operations regulated by computers. By providing increased and varied modes of information the aesthetics of the otherwise rather sterile terminals may be improved. The improved stimulus values of displays may be made more interesting and this, in turn, may increase the strength of the motivation of students to learn.

Generally, individuals are isolated in or at terminals. The carrels are isolation booths, used to eliminate interference, to control noise and to accentuate the individualism of computer learning. The development of pluri-individual terminals has been neglected even though much learning occurs normally in social-personal-interactional situations. Pairs of individuals using single sets of programmed study units have been found to increase acceptance of somewhat dull programmed instruction. Particularly in language instruction that is computer regulated, two people might converse and interact with each other as with the stimulus materials. The two-man language and learning booths have not yet been developed for testing requirements of the social factors that are advantageous in learning. Children themselves are reported to personalize the computer instructions and in the Response Environment Project teaching assistants are close by and on call for the semi-isolated child.

Computer dependability is imperfect even at this late date in the development of computer technologies. "Down time" is tolerated by sophisticated people who work directly with and understand computers. It has been learned from early experiments with closed-circuit instructional television that school people are very intolerant of equipment failures. A few instances of failures may lead to complaints and rejection of the system on the university level. When applications are made to critical jobs it is often desirable to have two identical computer systems operating in parallel so that in case of the failure of one system the other can take over. It is reported that the Bowman-Gray Hospital in Winston Salem is being forced to consider this parallel computer arrangement.

Even restricted study of computer developments show that model after different model follow each other in rapid succession. The rapidly evolving trend during the past ten years in the computer industries is for larger and faster and faster machines. Shared-time and online patterns of use have evolved with some machines as one strategy for using excess computer capacity. These developments also make it possible for a limited number of small educational units to have computer services without having to afford the expense of a computer. The pressure on manufacturers to increase the size and speed of computers may contribute to the problem of lack of dependability in the late models.

The trends of new models of multi-million dollar machines also exhibits one antiquation factor which is unique for the educational enterprises.

The size and speed evolvement has provided in some schools, colleges and universities, an excess of computer capacities. This makes it possible, in some situations where the computer is otherwise justified, for instructional functions to be served by using available unused time and/or computer capacity and to do this at no cost or at special low rates. For the time being and during the research and development phases of computer regulated instruction the costs are great, so high in fact that it is not possible to absorb them in regular operating budgets for instruction. Studies are needed on the costs of terminal/hour units, and in fact the whole economy, actual and projected, for computer assisted instruction. The possibilities of increasing the utility of programs and of thus reducing unit costs also needs to be explored.

Earlier in this report I referred to the imbalance that existed between "hardware" and "software". The lack of balanced planned strategy for research and development of computer regulated instruction is evident, also, to all observers. Too many installations are working at the same levels of development, usually doing a kind of feasibility testing, even though the subject matter may be varied. As was the case for programmed instruction and teaching machines, elementary subjects are attractive. There would seem to be some urgency about drafting and putting into effect balanced and soundly planned strategies of research and development. Such a strategy should have the effects of reducing expensive duplication of work on some problems, e.g., drill and practice feasibility studies, and of increasing the efforts to solve other problems related to possible new uses of computers. A soundly planned strategy should also increase the range of feasibility explorations to varied subjects and to different levels of instruction of the whole educational system. Finally, the systems concept should be applied in planning. This would suggest explorations of many linkages of computers with other telecommunication media that already exist and have earned roles in education.

Clearly educators, governmental agencies, and industries all have large stakes in whatever develops in the area of computer regulated instruction. It is suggested, therefore, that one or two of the regional educational laboratories be given leadership responsibilities for providing conditions which will make possible wide cooperative efforts in the area of computer regulated instruction.

In this chapter a gifted educator, engineer and social scientist employs his vision of the technical potential of the computer and communications industries to provide the context for his examination of the social and political task of education. Alexander Shure has effectively dovetailed the inevitable advances of technology with their capacity for triggering problems and offering solutions. Minority - majority interaction, changes in value systems and vocational education, economic effects, and human needs are all considered in this keen analytic presentation. Having probed deeply into the problems and in the spirit of the true scientist, Dr. Shure resynthesizes the material in a series of wide ranging and constructive predictions and recommendations.

ASPECTS OF EDUCATION IN THE DECADE OF THE SEVENTIES

Alexander Schure

Social and Human Needs

For almost a century, educational psychology has been concerned with the problems of relating attainment to general intelligence. In recent decades, the literature of individual differences has been increasingly couched in educational terms. As educators, we tend to think the problems of developing and releasing talent can be solved by the school. Actually, the solutions are essentially political and social.

A free and open society which attempts to recognize the marvelous uniqueness and value of every individual must also have the wisdom to realize that the school can do justice to the community only when its educational framework is truly integrated into other social formats. When we examine the persistent problems which impede the education of a wide spectrum of our children and youth, and relate the efforts of our school system to cope with them, our concerns for achieving better "solutions" in the immediate future seems appropriate. A high priority, in the next decade should be given to meaningful extensions of educational forces into close partnerships with other social agencies.

Cost of Education

Problems

Education is a precious but expensive commodity. In these United States, directly or indirectly, it now consumes an annual expenditure of almost one hundred billion dollars. As presently organized, and despite all efforts to date, our national education programs cannot keep pace with the enormous demands placed upon them. Sufficient manpower is not available for the task and resources are never adequate for the population to be served. Without dramatic intervention of available new techniques, the situation will not improve in the foreseeable future.

Widening Range of Education

The pressures on the educational system are intense. The increasing diversities of learner age and background range the gamut from pre-schoolers to aged adults - almost literally "womb to tomb" concern by educators for pupils. The ever increasing numbers of learners demand new arrangements of informational services and of teacher training. Also required is increasing emphasis on research into the total mechanisms of social change: on the identification of emerging meaningful innovative processes and the development of means to introduce them into ongoing operations successfully; on methods whereby the technologies applied to the education process can contribute to humanistic goals; and on our most basic educational concepts, problems, and beliefs.

The Dropout

The present educational system when examined shows evidence of major stresses. Our elementary schools are plagued with less than satisfactory levels of achievement for the heterogeneous groups of pupils they serve. Further, the schools are now faced with adding to their already overburdened operations a vastly expanded post-high school education as the minimal career requisite of an increasing segment of our population. Because these pressures are now critical, and despite concern for educational excellence in rural, suburban, and urban institutions, there arises the incongruous result of educators tolerating the large number of high school and first year college dropouts, and the even larger number of students who exhibit failure patterns or extremely low attainment levels in one or more courses in their academic experiences.

Occupational Training

To this waste may be added a lack of relevant occupational training, misdirected career and curriculum guidance, and arbitrary academic behavioual objectives often set by tradition rather than realistic needs. Inflexible and inappropriate instructional pacing often is dictated by administrative convenience rather than the actualities of student performance. Often there is no use made of successful innovative educational practices, models, and methodologies as a result of lack of information and know-how. Thus, the usual educational establishment lacks a sufficiently rapid feedback on which to base corrections for deficiencies due to inadequacy of environment, resources, and methodologies; mismatch of teacher and learner; insufficient prerequisites and preparation; poor learner attitudes; or the innumerable other tangible and intangible factors which influence the efficiency of the learning process. It is little surprise that talent and funds are eroded by inefficiency.

Urban Education

Present educational efforts in the urban areas are piecemeal and often ineffective. Yet, unless the emergency status of the crisis is recognized it is questionable if there will take place the reorganization of existing agencies, the Federal and State expenditures, and the development of necessary new patterns required to deal with present problems of the urban areas, their inner cores, and the people who constitute them.

Human Needs

We require broad-based, focused programs which are feasible economically and operationally; are directed towards both majority and minority groups; point to long objectives, begin with preschoolers and continue to the adult; and aim at stabilizing the inner city by providing means through which the requirements and desires of minority groups (Negroes, Puerto Ricans, and others) can in actuality be met. The needs of these constituents go beyond welfare, employment, and minimum education. They include as a high priority the maintenance of dignity for the individual; his ability to exercise control over decisions that relate to his own life; and the means whereby he may develop his resources in directions that yield promise of substantial future returns to him. Solutions will be found in programs acknowledging the interactional relationship between majority and minority, and directed towards the values and belief systems of whites as well as Negroes and other minorities.

Education must prepare people for consistent performance in some socially valuable activity. This means servicing not only the intellectually gifted or the academically talented, but those who must function capably in a range of prosaic occupations, in the graphic and performing arts, in the technical crafts, and in social leadership. An educational format capable of satisfying so many interacting logistical and economic demands is among the objectives of the next decade. To accomplish this all the tools available within sophisticated business management, all relevant sciences, and all applicable technologies must be utilized.

The current trend of applying management techniques to many processes, whether in industry, the military, or education, is not a fad. It is a serious attempt to improve the efficacy of ongoing systems. In recent applications to education, it is an acceptance of the necessity to measure realities and outcomes against hypotheses, to re-examine "axioms," to replace armchair judgments by empirical findings, and then apply the results in subsequent decisions. In most situations the computer becomes an indispensable aid to the process. Through its capacities, there can evolve a more efficient educational format by using a management approach as a method of solving aspects of the educational dilemma which now confronts the nation.

Among the more dramatic vectors which will help produce major gains in education are: concern for individualized instruction, technologies ranging from computers to TV, from teaching machines to behavioral gaming, making available new kinds of techniques, teaching materials, and tools for diagnosis, prescription, and application; increased sums of money available for education; the interest and intervention of large-scale business in the education industry; concerted efforts in research such as those underway in the National Educational Laboratories programs; and, most important, a genuine acceptance at national, state, and local levels of the broad social objectives of education for all, coupled to a re-emphasized recognition of the potentials of education as the means of achieving a truly eminent society.

The transformations affecting education today will bring about marked evolutionary changes within the next decade. Underlying many of the present trends is a growing base of psychological research which gives practitioners a greater understanding of how people actually learn. The behavioral sciences are making the art of teaching easier to acquire and to assess.

If the overriding concern in the next decade focuses on the changes necessary to make universal education possible, a meaningful description of what universal education includes must be found. Needs run the gamut - pre-kindergarten education at all social levels for our children; schooling for the present conventional spans; programs for adults who require retraining; liberal, occupational, and professional education; education tailored to the normal, the handicapped, the retarded, and the gifted. We can also identify some of the important directions that must be followed to achieve this goal. Beginning with our new and major commitment to education, we must identify and nurture our talent, exploit the potential afforded by new systems of instruction, eliminate the artificial dichotomies in education such as the separation of vocational and general education, do away with restrictions imposed by a student's financial capacity, and, in educating for a broad range of occupational clusters much earlier than we do today, engender capacities and respect for such occupations.

The model of an educational system of the 1970's, then, will undoubtedly reflect approaches aimed at the major segments of population now not served adequately by the present formal school configurations. The approach of using occupational training as a vehicle for teaching general studies will be considerably more predominant than it is today. One concept underlying this course is the expectation that students who are less gifted verbally will be able to learn general education content more quickly through the use of occupationally related educational techniques. The second major goal is early, consistent, and occupationally gainful training for those who do not complete the academic mainspring programs. Whatever the viewpoints with respect to the utility of this theory, it will be developed and tested fairly in the next decade.

The Current State of the Computer in Education

What is also logical to expect in the next decade is that much more education, and indeed much better education, will be the fundamental prerequisite for progress. The intellectual level, and adaptations required of the students of the next generations will be considerably beyond those of now. The citizen of tomorrow must be both at ease among and capable of coping with a vast new array of techniques for processing information. The ability to yoke the capacities of the most promising tool, the computer in order to solve the problems of civilization will make it an essential part of all education, occupational or liberal. The use of the computer will alter the face of education, and indeed of civilization. The computer will be imbedded as a prime foundation stone in the schools, education centers, and universities of tomorrow. It will be a tool used locally within the classrooms as well as a management device to administer large regional school systems.

The information and computer sciences are beginning to demonstrate almost unprecedented capacities for improving the overall operation and functioning of education. Three major advances in computer design are responsible. They are: the development of large-scale multi-user, multi-purpose time-sharing; the development of techniques that permit direct interaction between students and computer based information systems including the development of natural languages for easy communication, and the increasing sophistication of educational data systems.

The computer is an optimum instrument for performing repetitive, time-consuming tasks. Since so much of a teacher's time is spent executing the oft-times dull and always exacting tasks a computer performs so efficiently, it is logical that the educator turn to computers for help. Use of the computer is merited wherever recording or analysis amenable to a complete computer accomodation is either tedious or involved, and frequent. In these situations, the obvious merits of the computer lie in its capacity to solve organizational problems ranging from simple to complex since the instruments are programmed to yield the necessary routines or working methods the human investigator requires.

If substantial advances have been made in the short time that computers have been used in the educational world, greater ones are on the horizon. The substantial savinge of man-hours and tedium, the interventions possible by computers in the direct education process, and the ability to examine new configurations more easily, all insure greater usage of the computer in the near future. The development of significant innovations in computer capacities (multi-programming capabilities, better problem oriented languages, improved ancillary equipment such as CRT display tubes, teletypewriters, and data transmission units) will bring the computer into more common use for education.

Indeed, the educational benefits resulting from access to a modern computer are many, and multiple sophisticated approaches are not far off in the future. The priorities of such usage and the thrust of approaches are of concern. Society must plan for the use of the computer now, and must specify the values it desires. Application of computer techniques to any phase of education is a valid subject for concern and questioning. It is equally important, as we proceed with introduction of technological innovations into education to query in advance and then to verify empirically the environmental impact of these innovations. Educational decision makers require a full evaluation of the social and economic costs involved, the benefits obtained, and the effectiveness of the measures introduced during the commitment to a new technology.

The forerunners of the computer organizations that will service the model schools of the 1970's are already in existence. A number of organizations are already exploring applications of the computer to education. They seek, through modern computer technologies, to raise the present low levels of school data processing to the sophisticated level of business and industry. They also seek to develop, in private and public education, those quality control techniques which can result in optimized, logical, effective decision-making. At present, the computer "outputs" which form the major portion of their services usually include: a) creation and maintenance of major files containing standard information about students; b) attendance accounting to yield automatic preparation of a school's attendance register as well as individual student attendance files; c) test scoring and analysis oriented to a school's particular information requirements and guidance practices; d) grades or mark reporting, recording, and analysis; and, e) scheduling. The latter has proved an excellent introductory vehicle to orient school administrators to the computer's potential for instructional programs. Since the computer is capable of handling the confusing multitude of variables involved in efficient utilization of the school's fundamental resources of students, teaching staff, and available times and spaces so as to schedule the individual student most effectively. Scheduling, then, introduces administration, teachers and students to some impressive albeit conventional, potentials of the computer.

Principal employments of computers in education to date have included:

1. Researching data base systems, programming systems, artificial intelligence, information processing, language processing and retrieval, behavioral gaming and simulation, mathematics and operational research, and education and training.

Applications

2. Computational aids
3. Problem solving
4. Simulation
5. Tutorial dialogue
6. Information retrieval
7. Testing and analysis
8. Guidance and counseling
9. Data processing
10. Management - of total systems and of items 1-9, singularly and in combination.

One of the more widely publicized innovations in education today is computer assisted instruction. Future adequate development of computer-based instruction will require extensive research involving re-thinking about the total role of the computer in education, and of the functions of education and teaching. A criticism of much of the work done to date is that most available "computer assisted instruction" represents little more than programmed instruction fed into a high power machine. The very fact that many questions remain to be resolved relative to computer assisted instruction indicates the dangers inherent in approaching its implementation thoughtlessly or with excessive rapidity.

Computer assisted instruction has fantastic potential, yet wisdom in implementation will be required if its strengths are to be realized. More and more American school systems are becoming involved. If their major exposure is to the present formats which largely provide only supplimentary curriculum materials, or drill and practice routines, the net effect may be that these school systems will drop computer-based instruction in the same way they did educational television and programmed instruction. Our existing schools rarely have the capacities needed to carry on program development in the carefully controlled fashion required to bring about full sophisticated utilization of computer assisted instruction. Most of the schools of the 70's will probably be no different in this respect.

Development of software for conventional CAI systems is already shifting towards the industrial companies. The reasons are apparent. Manufacturers can afford software development - most school systems cannot. The present estimated cost of developing one hour of meaningful, validated CAI materials is approximately $30,000. Also, at current stages of development hardware costs are very substantial, and the amortization of early developing software negligible.

Ongoing research indicates the possibility of computer generation of materials by algorithmic applications. Research is still sparse in critical areas, particularly in adaptations of materials for different cognitive styles of students and with respect to how teachers feel about using either computer assisted or computer mediated systems. Two present trends will apparently continue - the development of the tutorial mode and the writing of instructional prescriptions to provide individualized instruction for students.

Some of the economic problems associated with the use of CAI will be attacked in the decade of the 70's through more effective timesharing satellite linkage, increased off-line applications, and scheduling via computer of pupils into homogeneous or alternative logistical groupings. Such shifting class groups will permit special tutoring by selected computer strategies optimized to remedy specific learning difficulties. A high-yield, pragmatic application of the computer will be its capacity to provide dependable information relative to educational products. Properly organized, the computer can provide, from a base of continually updated information, such descriptive, analytical or empirical information as permits meaningful decisions about the suitability of selected administrative or curriculum systems, experiments, or instructional materials. It can also guide the restructure of materials to meet the behavioral objectives of a specific educational system more precisely. The systematic assembling, coding, analysis, and restructure of programs through computerized means will allow meaningful evaluation within the involved school. Transfer to equivalent school settings then becomes possible.

One of the keys to deciding what role the computer should play in instruction will be the teacher-to-student, the computer-to-student, and teacher-to-computer relationships. It has already been noted that the real power of the computer in education may be its capacity to make generalizations about student performance, to monitor the ongoing learning process, and to pick up patterns of response indicating the cognitive learning style of the student. Educational computer usages must go beyond mere facilitation of learning to clarify learning processes. They must make the student and all decision-makers involved with the educational processes more aware of what the learning process in ongoing operational situations actually entails, and the ways in which the knowledge that results can be utilized to permit the student to cope effectively with the environment which surrounds him.

If the prime thrust in utilization of the computer in the schools of the 70's will be towards individualizing education for large numbers of students with very diverse characteristics, there is a con-commitment need: the schools of the 70's must conduct a total analysis of their educational philosophy, planning, and operations, to ensure they are capable of responding in the most successful way to the diverse needs and abilities of all their students. The management system will characterize the operations of the schools of the 70's to improve the student's learning both throughout the curriculum and within subjects. Such management involves systems analysis and design integrating appropriate educational sub-systems analysis and their combinations into an organized model. Among the major educational sub-systems comprising the model are:

1. Goals (curriculum objectives expressed in behavioral terms delineating precisely the substance of the educational program, the skills and knowledge to be learned).

2. Students (as inputs to the system; with profiles, academic levels, proficiency attainment and all other data relevant to selection and subsequent education).

3. Curriculum (course content: the software or programs designed to accomplish specifications of (1) above).

4. Instructional strategies (the combination of methods, media, and organization required to conduct the learning program).

5. Assessment (tests and other assessment procedures ranging from student performance through program cost effectiveness).

6. Instructional Decision Making and Prescriptions.
7. Feedback and Restructure Mechanisms.
8. Organization and Facilities (facilities and equipment, plus faculty and other personnel required to support other sub-systems).

The proposed management system will be so designed that it will be capable of being applied at virtually any educational level, and so that it will develop procedures to optimize the design of instructional systems. It will be necessary to implement and test the model by applying it to selected school systems and their students. Further, the pioneer schools of the 70's will be organized to test the model on both academic and occupational programs. It will evaluate the cost effectiveness of the program both in its tooling stage and in its operation, and optimize performance of a heterogeneous student population by identifying those resources best suited to meet the needs of particular student groups.

Educational Innovation

The efforts to accomplish meaningful improvements in education must of necessity focus on concrete problems and activities. The decade of the 70's will see a structured intertwining of school and community organizations representing initial, sensible, developmental solutions to some of the crucial problems now facing society.

Comprehensive School Districts

The most probable formats, as our social and educational institutions move to offer successful, appropriate, and attractive learning experiences for all the youth they serve will, in all likelihood, lean to the development of comprehensive school districts. The more comprehensive the system, the more successful its capacities to organize total necessary education and social programs will prove to be. "Comprehensive" means all resources - the community organizations, educational agencies, labor unions, industrial establishments, business organizations, the technical schools, the colleges and universities all joining to make a total upward-bound educational social program possible. In a conprehensive district, the educational guidance and restructure of offerings then becomes far more flexible in range and depth than, for example, the power assembled in the single high school. The administrative organizations of such a district are characterized by specialization capacities in individual schools within the district available to all through regular sessions, extended day, year and evening adult programs; and by vocational, professional, technical, cultural and remedial programs with mobility between and within them. These must be coupled to a producing resource center which provides a great diversity of ways for its students to succeed, and to the social and business resources within the district. Its assemblages represent more than just educational facilities alone. The comprehensive district chooses, as its prime objective, the goal of educating all of its pupils through a zero-reject tradition - a total socio-educational program.

The organizing of educational services and the complexity of educational resources of such an organization require a special management system (to which the computer potentials previously described, are highly responsive), and a staff trained in a zero-reject tradition. The latter requires adequate communication among and between all elements of the applicable power structures.

If experience is a criterion for future judgment, first experiences with model comprehensive districts will deviate from their idealizations. Often, such deviation will be traced to a lack of precise stipulation of objectives, lack of integration or resources and disciplines into a functional unity, and the failure to evolve evaluative measures against which the desired outcomes can be assessed effectively. Eradication of these difficulties will yield a truly operational system. It should be noted here that the successful implementation of operational, pragmatic models will result in a more rapid incorporation of the system into national educational facilities on a wider-spread scale.

The Systems Approach in Education

A discussion of a total structure computer-managed pedagogical system cannot be concluded without a re-emphasis of the importance of systems, systems analysis, and systems operations. The vastness of modern education dictates that the value of any new educational innovation is largely determined by its integration with the other resources and components of the educational system. It is imperative, therefore, that there be a systems integration of all the available resource components, with the unique potentialities of every element aligned to produce a more effective system as a whole than any resource used singularly.

The comprehensive school district represents only one pattern promising success. There are many others of merit, but their introduction may well be delayed. Overcoming the lag in the capacity of an educational system to respond more adequately to those not presently served well will require understanding and utilization of the mechanisms of social change. Human nature may prove more of a problem than the ability of the experts in efforts to give a community a truly adequate educational organization. Human factors ranging from indifference, lack of comprehension, anxieties, misunderstandings, and the safe-guarding of vested interests, to outright hostility of participants or supporting cadres often limit introduction or maintenance of meaningful innovations. Considered together with administrative complexities, possible leadership inadequacies, faculty attitudes, budget implications, and special design considerations for facilities, the problems which restrict implementation of advanced systems and computer oriented developmental programs in contemporary education become clearer.

Planning and Research

There is a need then, to begin considerable planning now for successful introduction of major innovations into the educational models of the 70's. Education of faculty to the capabilities of man-machine systems is a prerequisite to education of students using machines. Since teaching and supporting staffs play a fundamental role in the use and adoption of industrial technology, strong consistent educational leadership must be available. It is the obligation of such administrators to lead the faculty and staff to the skills, programs, and states of mind which will permit maximized use of the technologies. For the short term, workshops, development of in-service programs, and joint administrative-staff planning at early points in the decision process all help. Longer term, there is a pressing need to insure that the behavioral science concept of instructional technology, now just developing from its early stages, be related closely with instructional practice.

Discussions of the state of the art of computer assisted instructional systems[1] emphasize their potential for responding to individual differences, as well as the problems relating to their introduction and effectiveness. Logic, and the trend of present developments continuously lead to considering the totality of the educational structure and give weight to the argument for managemant through systems, systems analysis, and systems operation.

The Communications Explosion

It should be noted that the development of the computer is part of the expansion of modern communication technology and should be regarded as such. Singly, and in concert with the computer, then, there are communication applications that will affect education in the coming decades substantially, and should be the concern of researchers. Some of the directions predicated herein are certainties, others are mere probabilities, yet all are or soon will be within the capabilities of the communications and information processing arts. Success in achieving maximum use of those potentials now available depends on willingness to give high priority to improving education through use of such techniques. Once such applications are truly underway, they must be characterized by a regenerative feedback pattern - use of the techniques to raise and diversify the educational level of all people the system serves - precise evaluations leading to increased effectiveness in using the communications media, leading to increased effectiveness in using the communications media, leading back to renewed effectiveness and creativeness for higher overall attainment with change and improvement of the system. There must be too, with the forhtcoming capacities for total retrieval of highly personalized information, provisions to safeguard the essential democratic rights that give man his dignity. Reason, intuition, and sensitive human judgements must temper and govern the use of total communication systems.

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[1] Gentile, "The First Generation of Computer-Assisted Instructional Systems; An Evaluative Review", A Communications Review, Vol. 15, No. 1, Spring '67, pp. 23 to 53.

Each communications breakthrough will have its subsequent families of applicable techniques, each advance its subsequent families of applicable techniques, each advance its ramifications into practicalities of new learning approaches. Thus, communications in the next decades will affect every segment of education in innumerable ways. Some particular examples follow:

1. Communications technology will be the prime instrument through which the creative time of free men will be enhanced. All aspects of our society from the competitive interplay of business and daily work tasks to the fruitful use of leisure time, whether for continuing education or the satisfaction of socially meaningful individual goals will be enhanced by increased usages of the capabilities of communications systems directly applied to educational tasks.

2. Lasar, infra-red, and other radiations, not now massively used, developed, or in some cases completely understood will provide the means for much short range communication. The result will be a considerable increase in the availability of automated assistance for the daily chores of man. With these automated to a large extent, the effect will be to reduce the need for thinking about minor problems of the day, and permit functioning of the human mind at a higher creative plane than would otherwise be possible.

3. The use of interrogation devices to produce automatic answers and verifications, without involving individuals in the process, will continue to expand. The devices used in the process will be myriad, from computer to automatic point finding radio transmission locations.

4. Within the next decade readily available applied communications technoloby will be far advanced from the present state. Size and weight requirements for equipment are shrinking now. The continued orders of reduction of operable devices will yield equipment existing as minute fractions, with respect to cost, weight, and size, of presently available circuitry. These results will make possible economies, reliabilities, and ranges of sophistication of devices beyond your present grasp. The reliability of

general purpose computers - those used for engineering, scientific, and educational applications - will increase markedly within the next decade. This improvement will stem primarily from the introduction of monolithic integrated circuits. The result will be computer systems which are new in terms of speed, high performance hardware, and reliability available to the consumer along with field-proven software.

5. Resultant extensions of present day communications systems and techniques will make for high quality and high usage of information retrieval devices, available to wider spans of age levels and heterogeneous population groupings than is now the case. Educational television, slow scan picture and data phones, video recorders, computer assisted instruction, instructional data processing and dial access systems, all already in use on the educational scene, will be commonplace as media for young and old in formal and informal education. The initial and most easily exploitable communication educational markets of the next decades will exist in providing "hardware" and "software" for such systems.

6. Biomedical engineering will advance from the present state of the art to a major role in enhancement of living and communications. Improved communications between man and nature will be developed or maintained as communication systems which include transducers replicating some of the unique sensitivities and capabilities of human optic, aural and nerve conduction become available.

7. Much more of the increasing storehouse of knowledge will be kept in electronic formats available for automatic search and replication. The magnitude of reduction in size and weight for storage of texts, as contrasted to present day conventional books, will be on the order of 1,000 to one or more. The equivalents of books, or segments of books, will be transmitted from electronic storage centers to the subscriber, in short time, via communications channels. Computerized electronic and automated cataloguing and indexing will be standard. Specialized libraries will tend to become interconnected with each other (Library or Universities) and with newly developed specialized proprietary sources (special services for the professions of law, medicine, etc.) The rate of transition from conventional to future will be governed by the economics of printing. Massive change is still on the horizon, and the next decades will not bring change from present day methods. Nonetheless, transmission of information as contrasted to distribution of books will become a major effort of the communication

related industries.

8. Increases in the use of educational teaching devices and industrial monitoring systems now becoming available to schools will release a meaningful percentage of teachers for higher level activities than the rote of conducting routines of present day classrooms. The educational institutions will adapt themselves to the potentialities of communications, permitting master teachers to play a more massive functional role in the teaching process. Creative and collective use of other exceptional minds not now engaged in the formal education process, including gifted artists, engineers and industrialists, will supplement the resources of educators through communications (telephone exchanges and seminars, video tapes, etc.)

9. The role of the formal institution will change. Communications services will change the logistical and economic patterns of present day institutions, extending them into business and the home. Similarly, industry will assume responsibilities for servicing larger portions of emerging educational needs in vocational retraining, business, industrial, military, home, and continuing education -- all as part of a direct marketing effort of total services rather than as equipment providers. Computers, harnessed to teaching machines and television, will bring a new dimension to public and private education, representing an unprecedented break-through in individualizing instruction, permitting instruction to students at that rate best suited to each individual.

Utilization and interpretation of computer techniques will go beyond mere data collection and dissemination. Combinations of contemporary mass media with modern computer systems will permit greater individual involvement in the decisions of society (through electronic opinion sampling, as one example,) and, hopefully, the organization and implementation of dependable innovations to realize our nation's high aspirations for the education of its citizens.

As with every new wave of in-migration, population shift, or economic crisis, education becomes a critical means of social adjustment. This was true during the several industrial revolutions, during the period from 1900 - 1922 and following our major wars and depressions. At such times, the methods and tools, as well as the philosophy, of education are examined more closely by many segments of the population to determine the irrelationship to the sometimes conflicting goals of the interested parties.

CAI is in such a state. The author, a well known sociologist, planner, and social philosopher considers the current upheaval in education and in society for its impact on educational technology. He concludes that the fate of CAI will not be determined by technical feasibility alone, but also by its effectiveness in achieving the intermediate and long term goals of education as a social-political force. The implications of this new method for changing the school and for meeting the needs of parents, teachers, and the community are evaluated. Its meaning with reference to depersonalization, and human values is cogently discussed.

This profound and creative development of the issues will be a valuable, indeed a necessary, tool for the policy maker, the social planner, and the educator in the difficult task of understanding and preparing for the future.

COMPUTER ASSISTED INSTRUCTION AND URBAN EDUCATION: SOME SOCIO-POLITICAL CONSIDERATIONS

Hylan Lewis

> "The common victims of the inadequacy of the school system have been the teachers and parents. And now they are turning on each other."
>
> Albert Shanker

> "One of the great failures is that we the teachers have not looked at the situation as a whole. We didn't dare to."
>
> Elliot Shapiro

> "...the danger is not so much that man will be controlled by the computer as that he will imitate it."
>
> Norman Cousins

This paper shares the main assumptions of every paper written by the members of the panel: the rapid development of more sophisticated and efficient CAI systems and devices is highly feasible; and their widespread use is inevitable. The systems and methods now in use are relatively crude prototypes. In confident anticipation, they are used to experiment and demonstrate, and to explore and map narrow technical dimensions of teaching and learning processes.

The added assumptions that underlie this paper relate to some of the sociopolitical, rather than technical, considerations involved in decisions about the content, emphasis, and application of CAI systems. They reflect the belief that the chances are getting higher that the things that will affect the ways in which CAI is seen and judged in urban centers will have relatively little to do with the state of knowledge either about computers or about teaching techniques. Further, the effectiveness of CAI systems will not be dependent upon the quality of communication between the computer technologists or systems designers and the teachers in the classrooms or upon the professional judgment or school administrators.

Judith Leitner, in a paper, "Problems of Teacher Education and Orientation," suggests that it is important for the teacher "...to communicate with ancillary personnel to gain knowledge of both the child and the available approaches to guide learning." Further, "...the teacher must be able to communicate needs to the technologist..." and there is "...also an inherent responsibility for the technologists to gain a thorough understanding of both sides of the teacher-learning process."

Although we are concerned with the teachers and technicians and their orientations to each other and with their acquaintance with "both sides of the teacher-learning process," this by itself would be a seriously limited and limiting view of both the components and the dynamics of contemporary education. Left out of consideration are dramatic changes that are taking place in the stances of teachers and parents regarding how education policy should be made, and who should have an effective voice in making it, particularly in the inner city schools.

Among the added assumptions of this paper:

1) The salient test of CAI in urban education will not lie in its technical feasibility; rather it will lie in whether it contributes to lessening or widening critical gaps between rich and poor, suburb and inner city, and black and white in the metropolis;

2) Community acceptance and consensus about CAI will hang heavily on the results of political conflicts in the urban areas among shifting combinations of teachers, parents, and administrators; of white and black; of old and new ethnics; of old and new classes; of ghetto and

non-ghetto residents.

At the same time that there is movement toward decentralization of school administration and policy making, and a growing emphasis upon local control over institutions and services, organized teachers, parents, and neighborhood groups are making simultaneous demands that their new claims to equity in school policy and administration be recognized and acted upon. Some organized teachers, and their leaders, such as in New York City, are concerned not just about income and conditions of work, but also about control over educational organization and technology. And, poor and Negro parents are becoming actively concerned not just about school buildings but about the quality and content of education, and the characteristics and attitudes of teachers and administrative personnel.

The new and vigorous insistence of teachers and parents sharing in decisions about what goes on in their schools represents a move toward a new political or civil status for these categories. Policy making in the urban educational process is becoming politicized in a way it never has been before in American education.

The fact that reactions among parents, teachers, and the professional administrators (characteristically the effective policy makers heretofore) are assuming this political cast is a critical development with clear implications for the use, if not the development of innovations such as CAI. One immediate consequence is a widening of community conflict about education. This reflects real and apparent conflict of interests, different priorities, and inadequate communication between teachers and parents. This conflict may be increased to a critical level if self-conscious and anxious parents are not a part of the same bargaining process in which the organized teacher negotiates for changes which directly affect the interest of the parents and their children as much, if not more, than the interest of teachers as a category.

Elliot Shapiro reminded a group of teachers of their new political status and changed community responsibility at the close of the recent strike of New York teachers:

> "I have been saying that children were not treated as citizens. But teachers were not treated as citizens. And teachers didn't treat parents as citizens.... It has been a system where you use power when you have it and are obsequious when you don't.
>
> The teachers in this system were the first to decide to become citizens. A union, if you will, was quite necessary to develop the sense of the possibility of citizenship. But, if you do not now accept the possibility of participation in the life of the school and of the community, you and I as teachers deserve to be

> driven from the schools.
>
> One of the great failures is that we the teachers have not looked at the situation as a whole. We didn't dare to."
>
> And because they were not free, teachers "...talk about the disruptive child and insult the black and Puerto Rican community.
>
> We did not know how to make contact with parents... . But we entered into this as though it were a labor-management dispute."[1]

The basic problems of public policy in urban education, and the basic functions CAI should serve to implement policy are not changed by the new conflicts, tensions, threats of violence, and the recent violence that are marks of the deepening urban crisis. The core issues of education have clarified by recent development and the urgency of major changes in attitude and commitment of resourses has been underscored. The problems are how to achieve not only better distributions of jobs, income, housing, and services, but also, and most importantly now, to curb the unnecessary invidiousness with regard to the social reputations of the poor and the capacity of poor and Negroes for normal learning, and their potentials for social adequacy and family stability. Many of the poor, Negroes, and persons who might be classified as lower class and lower middle class indicate that they have learned, and are more prepared to act on, something the middle classes and influentials have known or taken for granted! The answers to the questions as to whether and when the community is going to provide or afford them the means, the effective tools of competence, and more life options, depends more upon how the community is organized than on how they behave as individuals. And it has something to do, as well, with whether, and how, they are organized.

It is in this context that the significance of "Black Power" for education, and specifically for the introduction and reception of CAI, should be seen. Black Power is essentially a political development, a political response. It is the most dramatic by product of the recent politicizing of race relations in the United States. Black is undergoing an aggressive and rapid upgrading. The aggressive affirmation of black is partly instrumental, inasmuch as black is an effort to draw an unambiguous political line between Negroes and whites. This dramatic inversion of symbols and change in the social connotations of color, changes the name game for many Negroes and whites. It is not just all right to use black, it is indicated and demanded in some quarters. It reflects shifts in program aims and priorities. It is marked by the emergence of a different language, and the vogue of another kind of logic, and these too are most pertinent for educational planning and administration. An important aim of the politically-conscious movement and strategies, rhetoric, and stances related to the slogan "Black Power," is to increase consciousness of the importance of Local Power. And it is meant to emphasize that powerlessness can be described through participation and sharing in the control of local institutions. To make local schools more responsive locally, for example, has high priority and appeal because of the value placed on education. The design of the ghetto resident for increased participation and sharing may have as its goals anything from improving personnel competence and attitudes, in order to redress past failures and prevent their repetition, to making the course of study of the school. The point is that even if the question of whether CAI should be used is not at issue, the chances are that inner city Negroes and the poor will show prime, and sometimes aggressive interest in the content, as well as in the assumptions, and technical efficiency of CAI.

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[1] Quoted in Murray Kempton, "Fear in the School," New York Post, September 29, 1967, p. 49.

Under some circumstances, the local urban poor and ghetto Negroes, when made acutely conscious of their powerlessness, will be inclined to trade off any presumed advantages of innovations in educational technology, as in CAI, for control over, or a larger share in, school decisions. Under other circumstances, CAI may be accepted or "bought" as a means of hastening training or rehabilitation.

In any event, the stance toward CAI of the urban poor and ghetto Negroes who seek to control or to share significantly in school policy is usually a highly pragmatic, although at times it might not appear to be so. This stance will tend to vary in the near future according to how it is related to the priorities given to control and to re-orientation or reconstruction of the schools. Any of a large battery of attitudes and values might become salient in these situations - quality education, achieving larger share in control of schools, changing content of schooling, negative reactions to the invidiousness in some generalizations about teaching poor and Negro children. One of the imponderables in introducing educational innovations like CAI is which differences in usage and context are likely to be rejected, which are likely to be accepted, and which are likely to be insisted upon.

Generally speaking, when there are differences in the quality of educational services and when there is disproportionate use of remedial, and rehabilitative techniques - unless the decision to use them is shared and understood - the chances that approaches and facilities are likely to be resented or rejected are high. When the usefulness and place of remedial and supplementary devices for achieving quality education, and for bettering chances to compete equally, are understood, when control is shared, and, importantly, when the initiative to use different educational approaches and techniques comes from the group or community, they are likely to be accepted; and sometimes they will be demanded.

When the subject matter that is programmed is seen as excluding, minimizing, or distorting the roles of Negroes, Puerto Ricans, Mexican-Americans, their experiences and contritutions to American life, it is likely to be rejected. Further, there is likely to be strong insistence on setting the record straight and redressing racial, ethnic, and class imbalance, especially in what is included in curriculum content and history.

Innovations which are seen as having little more than making existing practices more efficient, and more impersonal, are likely to be matters of deep concern to parents and students in inner city schools. Unless introduced properly and supported by changes in relations between teachers and students, the computer stands to compound the impersonality, the dissociation between teacher and students, the depersonalization, and the sense of unfairness that already exist in the inner city schools. This climate and these attitudes and feelings are in some measure associated with scientific devices and pseudo-scientific language - powerful (in effect on lives and opportunity tests and measurements and unqualified concepts and popularized theories. Add to this the recent record in education and welfare of the embarassingly quick adoption, subsequent modification, and eventual discarding of some fleetingly influential theories and findings about behavior, motivation, cognition, learning styles, child rearing, and the basis for some skepticism among poor parents and students becomes clearer. There is a great deal of skepticism and resentment in the inner city schools, especially among Negro teenagers in the junior and senior high schools, about counseling services. In the main, these have to do with the attitudes of counselors and the informal organization of the school. Characteristically, arbitrary views of what is good for Negroes and poor children as categories and what are realistic goals for them affect the advice given: they frequently blot out other considerations.

A description of the attempt to test the usefulness of CAI in vocational counseling that is now underway at the System Development Corporation in Santa Monica, California provides an ideal picture of an approach that could either reinforce bias in an existing system or that could reduce it. The assumptions and the programming of the system are the keys.

Under such a system the automated interview would be designed to help the student select a college, plan his academic program and help him to explore the world of work.

The stated objectives of this research are to test a laboratory model of a computer-based counseling system, and "the publication of a research report which makes explicit the basis for counseling decisions."[1] The question is - what variables are put in the laboratory model?

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1. R. B. Otte, "Computer Assisted Instruction," Human Resources Branch, Division of Adult and Vocational Research, U.S. Office of Education, p.7 (mimeographed, mid).

Will the complex interplay of race, ethinc, and class perceptions of students, teachers, parents, administrators, and researchers be included: In some situations they are likely to be decisive in the working and outcome of the counseling process.

Kenneth B. Clark's description of some of the effects of counselor's perceptions, biases, and quasi-scientific judgments on the chances and behavior of Harlem youngsters in informative and cautionary in this context:

> "One suspects that the children's level of motivation is, to some extent, set by their teachers. One guidance counselor said: 'The children have a poor self-image and unrealistic aspirations. If you ask them what they want to be, they will say "a doctor" or something like that.' When asked, 'What would you say to a child who wanted to be a doctor?,' she replied, 'I would present the situation to him as it really is; show him how little possibility he has for that. I would tell him about the related fields, technicians, etc.' One suspects, from this type of guidance reinforced by poor teaching and academic retardation, that the poor motivation and absence of a dignified self image stem from the negative influence of such teachers more than from the influence of home and community."[2]

The chief theme of this paper is that the key problems of computer-assisted instruction in the metropolis are likely to be socio-political. They are a part of the current crisis of the metropolis and of the country itself. They are tied up more with the speed with which we move to prevent the gaps between rich and poor, Negro and white, ghetto and suburb from widening, not to mention reducing them, and their costly and fateful consequences, to the barest minimun. The metropolis as a decision-making arena is different, and the spatial distribution, stakes, and vested interest of the urban actors - whites and non-whites, mainly Negroes - are different from ten years ago, and from a few ago even: and they are still changing.

Relations among urban ethnic and racial groups, among the old and new classes, and among the lately organized, public service occupational groups and the public as employer give a new political dimension to community life and to the control over public services. Race, class, and public service callings have assumed new political relevance, and this is seen in clear form in the manner in which equities in decision making about urban education are disputed.

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[2] Clark, Kenneth B., Dark Ghetto, Harper and Row, p. 133, 1965.

This emphasis upon the fact that relations in the public area among the various groups with active and vital stakes in education stresses the need not only to be aware of the new political salience of teachers, but necessarily of parents and leaders in local neighborhoods.

Planning for CAI must see and respond to the whole picture - the total spectrum of potentially organized, and organized power segments in the metropolis. If the awareness and responsiveness of the planner in the area are weak, and, if as David Sarnoff points out, his postulates are wrong, the spread and wholesale adoption of computer aided instruction can only be "a massive enlargement of human error." Participation of parents and students in planning and programming are the best antidotes to bringing the wrong postulates to the application of CAI. That this is political, should not bother the planners. The type of political activity helps protect him from error and dehumanizing.

Russell P. Kropp is one of the handful of educational researchers who has a first hand knowledge of the development of CAI. Thus he combines experience with a keen analytic approach, and brings them to bear on the educational and logistic problems confronting this new field. His discussion ranges from the danger of the "atomization" of education, and computer effects on cognitive processes to the economic issue of cost-benefit and the administrative problem of personnal needs. He describes a rational and practical approach to the issues that were raised in the Seminar.

MAKING CAI WORK

Russell P. Kropp

The remarks presented here are organized into two sections: Observations, and Support of Research and Development. The comments in the section on Observations consist of insights or the deepening of previously formed opinions due to the Seminar. These are merely products of the interaction of the interests which the writer took to the seminar and that to which he was exposed as a Seminar participant. They are not intended to be representative views of fellow participants. The section on Support of Research and Development conveys the writer's opinions about the needed role of near-term support of research and development in CAI or, more accurately, in computer applications to education. A possible role for the Federal Government is emphasized. These opinions are presented tentatively, but with the hope that they merit some consideration.

Observations

CAI as a Special Case of Computer Applications to Education

It became increasingly clear as the Seminar progressed that computer-assisted instruction (CAI) is just an instance, perhaps not a critical one, of computer applications to education. The usual meaning of CAI is the computer storage of instructional materials, the presentation of a part of them to the learner, the evaluation of the learner's response, the choice of the next item of instructional materials, etc. Thus, one might regard CAI as an instructional system which functions independently after the appropriate programs are stored in it. If this is acceptable as a working statement of CAI, then many computer applications to instruction and to the educational establishment fall beyond the boundaries of CAI. Therefore, to confine these remarks to CAI would ignore almost completely those dimensions of the revolution in education which the computer has and is precipitating. The writer believes that CAI is inseparable from computer applications to education; so the subsequent narrative deals with both. However, some emphasis is laid on CAI.

CAI and Computer Applications to Education Are Realities

Computer applications to education and CAI, as an instance of it, are regarded as shadowy events looming distantly on the educational horizon; or less positively, as potentialities; or, not infrequently, as pipedreams. Concrete evidence about the extent and variety of current educational uses of computers quickly dispels the notion that these are merely something which might occur. They are a fact now! Whether to use the computer as an educational tool is a question which was appropriate and timely a decade ago. But it is no longer. The pertinent and present question is how to provide for the optimization of computer applications to education. This question has many ramifications for public schools, colleges and universities, the Federal Government, business and industry, etc. Time answered the "whether" question; the "how" question remains to be answered reasonably.

Wide-Range of Computer Applications to Education

Present use of CAI by public school, college, and university is experimental. In a few isolated cases it is or will shortly be employed in routine instruction; nevertheless, the usage might rightfully be regarded as exploratory or experimental until the effectiveness of it is determined. On the other hand, computer applications to education in the broader sense are increasingly more common. The computer is used for pupil accounting and reporting, test scoring and reporting, inventory control, class scheduling, student registration, etc. These are established usages so they can no longer be regarded as innovative. When judged according to this broad perspective of computer application to education, CAI is simply another application to a system which has proven to be an hospitable host.

There are other applications which probably will be implemented simultaneously with CAI or quickly follow its introduction. Developmental work is now underway on computerized placement and guidance services, instructional management systems (in contrast to instructional presentation systems characterized by CAI), educational games, calculating and simulation capacities as instructional aids, etc. Therefore it is necessary to consider the eventual implementation of CAI against a background of prior acceptance of computer applications and simultaneously with a new set of applications each of which is as novel and significant as is CAI. CAI should not and cannot be considered in isolation from the relevant context in which it will be placed or from the other innovations which are contemporaneous with it.

The Interrelatedness of Instruction and Educational Administration

Projecting the future development of CAI, or any other computer application for that matter, cannot be done independently of the administrative structure and formal organization in which the development and subsequent implementation will take place. Many innovations having considerably less potential impact than CAI, were stillborn because the innovators failed to take into account their probable effects on the host's organization, power structure, roles, sociological and psychological forces, and sources of human satisfactions. CAI is capable of radically altering our traditional conception of education, particularly because of its potential for individualizing instruction. But if this promise is to be realized, then many problems which it will create must be solved rapidly. The role of the teacher will change and as a consequence teacher training ought to change too. The traditional prescription of five periods of a subject each week for 36 weeks of each year, in order to satisfy accreditation standards, will probably give way to measuring educational accomplishment according to mastery instead of exposure. If this occurs, scheduling students for instruction and maintaining achievement records will become highly complex problems which undoubtedly require the computer for their practical solution. CAI development and implementation will not proceed except hazardously without concomitant changes in the educational structure and the professional roles of virtually all school personnel. This matter deserves serious consideration. The writer does not believe that studying the ripples caused by implementing PSSC Physics can serve as a base for extrapolating to the tidal wave thich CAI and other computer applications will create. These innovations are of vastly different magnitudes.

Education and Schooling

Some of the Seminar participants and some of the groups which served as their hosts implied a distinction between education and schooling in their discussions about the future implications of CAI. If the writer understood correctly, schooling is that which occurs within a formal educational structure; e.g., elementary and secondary school, college and university, etc. Education is that which occurs during the life of an individual, is not confined to any particular period of life and is given only in part in the educational establishment. At various times the participants were urged to consider potential use in self-education, self-enrichment, vocational re-education, etc. were stressed as possible applications which should not be ignored, nor should the effects on society be ignored if these usages are realized.

Determining the Critical Entry Points for CAI Development

The variety and extent of problems directly associated with the development of CAI, coupled with the problems that it will create when introduced to the public school system, are very complex. If one wishes to identify problems which ought to be dealt with on a priority basis to assure a smooth period of future development, then he is bewildered by the complexity and urgency of each of the problems. It is doubtful that anyone has the wisdom to ferret out the key problems. It is more probable that a broad strategy of development will have to be formulated by the best informed people and then pursued without hesitation despite knowing that some of the decisions were arbitrary. Despite the imperfections of this method, it is more meritorious than unplanned and uncoordinated development which is shaped by opportunistic events, differential ability to capture developmental grant and contract money, persuasiveness of salesmen, persuasion based on novelty and getting on the bandwagon, etc.

Wherever one looks he sees problems which must be dealt with. The CAI languages in which instructional programs must be written are very primitive and severely limit the quality and sophistication of instructional materials which might be written. The student terminal is equally primitive and barely meets a minimum level of acceptability for presenting instructional materials and registering student responses. Programs for the on-line analysis of student responses--which are critical to the individualization of instruction, and the evaluation and improvement of the instructional materials--are virtually nonexistent. The criteria for judging the effectiveness of an instructional program have not been established. The evaluation of CAI instruction includes all traditional components plus cost effectiveness. Optimal usages of CAI for particular instructional tasks have not been established. The feasibility of using CAI as a medium for instruction in attitudes and values, group and social processes, and psychomotor skills remains virtually unexplored. The eventual compatibility of hardware produced by different manufacturers for presenting a given instructional program is an unanswered and highly critical problem. This list of problems is merely a sampling of those which are directly associated with or inherent to CAI. A far longer list might be presented about problems which will arise due to the implementation of CAI in schools; e.g., the interactive role of CAI, the teacher, and the instructional materials. The major and immediate task is to identify a strategy for CAI development that will capture its full potential and will propare the educational system for implementing and using it.

Possibility of Non-Computer Simulation of Computers

The Seminar participants and some of their hosts expressed concern about two issues which are related to the appropriate and optimal use of computers in instruction. First, there was some question about whether conventional instructional techniques are rightfully being adapted for computer usage when, in fact, the techniques are adequate in their own right and far less expensive to use in their non-computer form; e.g., the blind adoption of traditional programmed instruction as a mode of computerized instruction is a highly questionable practice. Whatever advantages might be gained through use of the computer could probably be gained equally well and less expensively with some simply constructed non-computerized hardware. Second, there was some feeling that some features of computerized instruction might just as easily and more cheaply be gained through inexpensive hardware which would simulate the computer and which might be under direct control of the learner; e.g., computer capability of presenting slides, film strips, and motion pictures might be adequately supplanted by off-line hardware like projectors which could substantially reduce the cost of computer hardware but would not result in less effective instruction.

These comments and others which appear in earlier sections are not indictments of CAI nor aspersions about its potential. They are intended merely to document the fact that little is known about the effective use of CAI, the optimal configuration of equipment for a given educational task, etc. It is imperative that these questions be kept in mind; otherwise it is possible that CAI will prevail, at least temporarily, because of its novelty instead of its realized merits and potential for significant improvement. Also, keeping these questions in the forefront might dispose one to be reluctant to support wholesale implementation of CAI at the cost of concerted and deliberate study and development of it.

The Impact of Computers on the Cognitive Development of Children

Some concern was expressed about the probable impact of computers on the cognitive development of young children and such implications as the effect on their perception of the world, and what kind of schooling would be most appropriate for them. This concern on virtually every aspect of daily life. Computerized banking and purchase and sale of goods are distinct possibilities, "computerized slaves: for doing housekeeping tasks are not imporbable; telephone access to instructional programs, libraries, etc., are viable possibilities; Although these computer applications might now appear to be romantic, they are probably no more unrealistic than were our earlier ones about television, space travel, and the computer itself. The argument goes that if computers affect all areas of life, then life will be significantly different from what we know it to be today. Undoubtedly these differences will have profound implications for the child with regard to his perception of the world and himself. His cognitive structure might be greatly determined by his computerized environment and by implication his pattern of thought might be unwittingly shaped by the mode of communication with and the logic by which computers o operate. In short, it is necessary that someone become heavily concerned about these long-term possibilities which will inevitably be confronted whether we have prepared for them or not.

Mastery versus Command

Most of the CAI applications are directed to discharging known instructional tasks. Effort is devoted to relieving a teacher of some instructional responsibilities and re-defining his role so that he can work optimally with CAI to maximize educational output. If one assumes that computers will penetrate all areas of life -- as they have penetrated business, industry, science, and now education -- then one might profitably consider how the goals of education should be altered to reflect new capabilities which the computer will provide. One example might illustrate the point. It is highly probable that the calculating capacity of computers will soon be available to the majority of students. Therefore one might inquire, whether it will be as imperative then, as it is now, for students to be highly proficient in mathematical calculation. Might it be more important and vastly more educative and powerful for students to be aware of a much wider range of mathematics than they are now and to have a command of the essential algorithms in the various fields of mathematics. Having an acquaintance with them and the range of problems to which they can be applied, students could command the computer to execute whatever calculations were needed. The capability of students to command the execution of a calculation is markedly different from his mastery of the details of that calculation. Perhaps this line of reasoning can be applied in other disciplines too. It might be timely to consider whether some educational objectives should be changed to reflect the advent of the computer.

The Atomization of Instruction

The comment which appears here is made with extreme reluctance because of the great likelihood that it will be misinterpreted. A major characteristic of the methodology used in developing course materials for CAI presentation is the painstaking analysis and re-analysis of content, presentation technique, and component learnings into their elemental particles. Hopefully these atomistic bits can then be structured serially into a meaningful instructional sequence which transports the student unerringly to the instructional goal with the same economy and efficiency that a perfectly shot arrow traverses the distance between the archer and the bullseye of the target. One cannot question the validity of this methodology. However, one cannot help but have misgivings about whether the combination of many of the instructional sequences so constructed will at all represent what occurs in the traditional instruction of students or will yield results at all similar to those of traditional instruction. To put it simply, the reservation is that CAI according to this mode of development might prevent the occurrence of the very meaningful and significant learning which occurs vicariously or opportunistically during the usual school day. The apparently fumbling and inefficient teacher who meanders to educational objectives which are not crisply defined might not be fairly characterized. To supplant or supplement him with a highly efficient instructional apparatus, as judged in terms of just one of the roles which he performs, might destroy or diminish the essential humanity and breadth of education. One cannot help but wonder if the teacher is really inefficient when he accepts a less than perfect response from Johnny simply to encourage him to continue to participate in the discussion, when he departs from his presentation and remarks that there is a parallel point in biology, when he sets easy tasks for Bill who is very much in need of confidence and mastery whereas he sets formidable tasks for Jack who is content otherwise to let a remarkable intelligence remain idle. These might be irrelevant from the standpoint of the instructional objectives but they are quite relevant from the standpoint of what might nurture the student most satisfactorily at a given time. One might argue that such considerations can be cared for at other times or in other ways, but this is not too satisfying because it means that part of the school day will be spent individualizing instruction in a way that ignores very crucial individual differences. The whole point of education might be missed if curriculum development is given over to non-educators who through slavishly pursuing a methodology of reductionism and a goal of cost efficiency might seize the most superficial goals of instruction because they are most amenable to currently available tools and techniques.

Computer Assisted Instruction or Computer Management of Instruction

Questions were raised about the probable path of future development of CAI. Although the major use of CAI now is to present instructional materials, there was considerable belief that this role would change to that of computer management of instruction. This emerging role might assign to the computer information about all students, instructional materials, course objectives, and intermediate and terminal tests, etc. The computer might then administer an entry test to a student and on the basis of the results of it prescribe a certain kind of instructional activity for a short period of time. It might be to review a film, to do the exercises which appear in the workbook, or to ask a teacher for help. Then the student would represent himself for examination and a new assignment, and so the cycle would be repeated until an adequate score was obtained on the terminal test. In the traditional role, CAI is largely an independent instructional system. In this emerging role, the computer is the manager or coordinator of an entire instructional system, the elements of which might not involve the computer at all. There are conspicuous advantages to this emerging role -- diversity of instructional media, reduced expense, flexibility -- which make it worthy of careful investigation.

Preoccupation with Cost Benefit and Cost Effectiveness

In most considerations about CAI, this question is the one most likely to be asked. How much does it cost in comparision to regular instruction? The exception to this occurs when the conversation includes the representative of a computer company who will undoubtedly answer the question before it can be asked. One might infer from this preoccupation about costs that the measure of CAI success will be whether it can do at the same or less cost what is now done in schools. Although it is reassuring to know that everyone is concerned about costs, it seems premature to worry about them. Concern might better be shifted to such questions as "to what extent and how can computers enhance the educational process," "what new kinds of instruction can be undertaken," "how might learning opportunities for students be maximized," etc. The current obsession about cost benefit and effectiveness might preclude exploring the unique capabilities of the computer for assisting the instructional process.

An equally exasperating aspect of this cost obsession is using "presentation time" as the criterion measure for judging effectiveness of CAI instruction. Educational achievement seems to be ignored as a relevant criterion. It might be ignored because a dollar value cannot be attached to it, a fact which industrialists discovered during the last few years and educators have known for centuries.

We Have the Machines but Who Has the Instructional Programs?

The one-sided development of CAI can be seen in bold relief by asking, "But where are the instructional programs?" The development and adaption of computer systems for educational usage have proceeded very rapidly. The absence of instructional software is a critical limitation. It prompts one to wonder if the production of the hardware in the educational sector were not participants in the developmental process.

Recent events relating to the production of instructional materials suggest that it will become a major responsibility of the industrial sector. Through mergers with publishing houses, industries have acquired some capability for undertaking this kind of work. If the present trend continues then it is likely that the major role of public school personnel will be confined to stating the objectives of instruction and relevant content. Specialists will undertake fabricating programs according to these specifications and evaluating the effectiveness of them. Whether this division of labor is ideal has had little discussion. But it is obvious that the situation is not ideal. The absence of instructional materials makes that patently clear. Educators, from public schools and higher education, and content specialists must be brought into the mainstream of CAI development because their conpetencies are precisely the ones which industrial participants seem to lack. The pattern of governmental support of CAI development must recognize this mutual dependency and therefore allocate its support in a manner which brings all who are qualified into a harmonious working relationship. One-sided support will dramatically prolong the development period and will create an atmosphere of distrust and hostility.

Support of Research and Development

The current status of research and development on CAI and computer applications to education is hard to assess. One difficulty arises because a large part of the work is done in industrial and military establishment. It is not easily accessible because of poor or partial dissemination and deliberate restraints on communication. The portion which is visible does not in aggregate reveal any overall plan for orderly, programmatic, and sequential research and development. This is surprising because the source of at least some of the support for the vast majority of public projects emanates from a single source, the Federal Government. (This opinion might be due to erroneous and partial information which is available to the writer; or it might be attributable to the infancy of the field for which the characterization is being drawn. The latter view is more tenable.)

The U. S. Office of Education is in an excellent position to provide a coordinated plan for research and development on CAI and computer applications. To give this leadership will require considerably more cummunication among all participants -- government, business and industry, and education -- than has occurred in the past years. It will also require a substantial amount of Federal funds and skillful coordination of the many sources of Federal funds to assure that the important tasks are achieved.

The remainder of this section is devoted to describing important features of such a program and commenting about current conditions which bear on them.

Research Training

There is a critical shortage of personnel who are qualified for responsible positions in educational technology, CAI, and computer applications to education. Demand exceeds supply and it appears that the disparity will increase unless support for training programs and trainees is quickly provided.

The shortage of qualified personnel becomes understandable when one considers the nature and history of CAI.. Its primary development occurred in the industrial setting. There has been very little exchange of professional personnel between the developing institution, industry, and the consuming instutition, education. One joint effect is that colleges and universities do not have adequate programs for training the kind of personnel who are in demand. It should also be noted that if research and development funds are awarded to the most competent people and organizations, then the bulk of it will go to industrial groups which have no tradition of providing advanced training for personnel who will subsequently enter the labor market.

To provide for the production and flow of trained personnel the government should establish college and university centers of excellence in CAI, technology, and computer applications to education. These institutions have traditionally discharged instructional functions; furthermore, there is little evidence to suggest that any other institution will assume this role to a major extent. But most universities will be unprepared for this role unless they receive major support in the form of equipment and facilities grants, personnel and trainee stipends, and operating funds. The current incapability of colleges and universities can be inferred from the very small number of them which applied for graduate-level research traineeship grants in CAI, technology, and computer applications under provisions of Title IV of the Elementary and Secondary Education Act. Where and how to establish these proposed training centers are questions which might be answered partly on the basis of current institutional capability, willingness of the institution to establish a high quality program, and the desirability of providing a diversity of programs.

The specialty for which training should be given is so new that is does not yet have an accepted name--educational technologist, educational scientist, educational engineer, systems psychologist, etc. It reflects a lack of consensus about the goals and components of an adequate training program. It might be attributable to the astonishing variety of disciplinary and professional specialists who are meaningfully involved in the emerging area--experimental, learning, and educational psychologists; statisticians; systems analysts and operations researchers; engineers of nearly all varieties; content specialists in most of the arts and science disciplines; educationists of every conceivable variety; communication and information transmission specialists, etc. Each of the proposed training centers should ideally involve different mixes of these specialists to give a distinct kind of training which would complement that given at other centers.

Research and Development

Research and development on CAI and computer applications to education might be reduced to three stages; basic research, pilot research demonstration, and mass implementation with continuing research. These divisions are artificial and imply only generally a temporal sequence. Nevertheless, they are useful constructs when assigning a temporal proirity of support to different activities.

It is doubtful that any one person has sufficient wisdom, knowledge, and foresight to create a viable and acceptable plan for CAI development. A most urgent task is to establish a forum at which all interested parties--industry, government, public schools, and higher education--can communicate freely and openly about their objectives, activities, and needs so that a coherent plan of research and development might be formulated.

The need for such a forum is highly critical in the case of CAI and is probably unique with respect to any prior educational or educationally-related technical development. The major impetus for CAI originated with industry and had only slight early support from the government. The government entered the CAI arena only in recent years and its plan of support is not clearly apparent. Education is undoubtedly the ultimate major consumer of CAI but it has been consulted infrequently and has not taken a significant role in helping to formulate a developmental plan which reflects its interests and needs. Consequently, the suggested forum would be valuable in planning a future course of action and also in uniting the major participants.

The forum might be achieved by establishing a national educational laboratory on CAI and computer applications to education.

The authority and precedents are firmly established for creating such an instrument. The national laboratory should be organized so that it would provide a meeting ground for representatives of industry, colleges and universities, the military, government, and public schools. It should not be as responsible for directly rendering educational service as are the regional educational laboratories.

The laboratory functions might be: (a) to provide a continuing survey and dissemination of research and development on computer applications to education, (b) to provide for continuing communication among all participants for the purpose of formulating research and development strategy, (c) to partition responsibilities insofar as possible among participants so that a division of labor in research and development is achieved, (d) to advise periodically the government about what policies it should establish with respect to CAI and to suggest priorities for allocating funds to activities, (e) to monitor and coordinate research and development projects on computer applications in public schools, colleges and universities, and perhaps the military, and (f) to foster the development of standards for CAI course materials and software systems which would be compatible for different computers.

Basic Research

As used here, basic research refers to the fundamental study of variables which underlie effective on-site employment of CAI; and excludes variables like machine languages, computer design, and other uniquely hardware problems which are left to the concern of industry.

Attention is directed to problems such as these: accommodating individual differences, organizing content for effective instruction, developing highly flexible natural languages in which to write instructional materials, specifying characteristics of instructional terminals which would provide a variety of stimulus and response modalities, devising techniques of on-line data analysis, identifying interactions of learner characteristics and the computer, optimizing retention and transfer, identifying what contents can be captured in the CAI mode, establishing optimal durations of machine instruction for different age groups, identifying teacher-machine interactions, etc. These are problems which should be subjected to basic research because the results will provide a foundation on which to build a development and implementation program for CAI. But it should be stated forthrightly that the development of CAI cannot and should not await final solutions to these problems.

The program of basic research could take many forms, one of which is described here. First, the training centers, which were mentioned earlier as a needed instrument, could also conduct research programs. The additional investment which would be required would be substantially less than it would be if the research programs were established independently of the centers.

Second, several research and development centers could be established similar to those now sponsored by the Office of Education. A minimum of two centers should be created; one dealing with CAI and computer management of instruction, and the other dealing with non-CAI computer applications to education. The specially established research and development centers should function more broadly than do the current centers. The new centers could conduct cooperative projects which industrial firms which have interests in the emerging technology, serve as test sites for computer systems prior to their being placed in normal instructional situations, and execute specific research projects recommended by the national educational laboratory.

Third, already existing research and development centers could be additionally charged with conducting research on applications of their special fields of interest to CAI. A collateral program of this kind is already emerging at the University of Pittsburgh Research and Development Center.

Fourth, project support should be available on an unsolicited proposal basis for CAI and computer related projects. Authority and procedures for handling such requests are well established.

A concerted research program of the kind envisaged here should redress the imbalance and danger created by having, on one hand, a highly sophisticated technological tool and, on the other practically no definitive knowledge about how it might best be applied and its probable impact on the organizational structure in which it will be applied.

Pilot Demonstrations

The program of pilot demonstrations could be a joint endeavor by public schools, government, industries, and higher education. These programs would require a very substantial financial investment. It could be underwritten primarily by the government (particularly the Office of Education and the National Science Foundation) and industry, and to a much lesser extent by the remaining participants. A strategy would have to be devised, perhaps by the proposed national laboratory, for determining the number and location of pilot-demonstration projects should be devised so that the opportunities for pilot research, development of instructional material, and dissemination would be maximal

The majority of pilot demonstration projects could be located in public school systems. A major focus of these projects could be developing and evaluating instructional materials because of the accessibility of students with whom to test materials, the availability of educational and content specialists, and the opportunity which it affords for studying the impact of computer applications on the entire school system. Active participation in these pilot projects could beneficially be required of the proposed training centers and the special research and development centers.

Mass Implementation

Mass implementation of CAI is several years off, but some preliminary decisions about the plan for it are needed immediately. The most urgently needed decision is to decide tentatively when the implementation program should begin. It should not begin until abundant software is on hand and the hardware situation tends to resolve itself. In this latter regard, a major consideration is the kind of computer which will be most useful in facilitating a variety of education tasks. Computers dedicated exclusively to CAI seem to be of questionable value for public schools. For the intermediate term, computers will be needed which can serve administrative functions, instructional use in the non-CAI sense, and some limited CAI functions. Also during the preliminary planning, consideration should be given to establishing regional computer systems which could serve a large number of public schools and thereby conserve human financial resources.

Not much careful thought seems to have been given to developing a plan for mass implementation. However, it must be recognized that some implementation is already occurring through government supported projects which are being undertaken by school system-industrial consortia. Perhaps the pattern for mass implementation has already been established!

It will soon be very evident to the reader why Dr. Frederick Duhl, a psychiatrist, was included on the panel. His response to the "human factors" approach, and his espousal of the human-serving aspects of the behavioral sciences and the new technology are prompt and sharp. He surveys the increasing responsibilities of the school and the gaps that educational research must fill to meet them. Dr. Duhl explores the technology for the enriching mix of learning forms appropriate to the complex capacities of people, while raising doubts about its present ability to do so. He reminds us of the potential of education for providing opportunities for the individual to function in a socially valued group and develop self esteem. His concern with the interpersonal effects of the computer and its implications for personal and social development add a significant dimension.

PUBLIC POLICY AND COMPUTER-ASSISTED EDUCATION

Frederick J. Duhl, .

In the following short essay, I will try to point out the parameters that are essential to the formulation of public policy and its implementation especially as it relates to Computer-Assisted Education.

First I will discuss the issues of values which are often considered but an esoteric appetizer before the main course: something to be passed over if it does not seem tasty.

Then I shall try to formulate the theoretical issues upon which policy decisions must also be based, so that educational activity is never unrelated to theories of learning and social process.

Next I will deal with the computer technology which is available and anticipated, and its interrelationship with people, rather than with "human factors," both in the immediate situation in which it is used and the social environment.

Finally, I shall raise the questions about the process of planning and innovation and end with a joke or a prayer or an admonition, depending upon my capacity to deal with the mood evoked in this essay.

Values

Computer-Assisted Education is a reality that will not disappear with the next change of Deans of schools of education, but rather will increasingly absorb the energies, interests and finances of the American education system in the generations to come. The computer as the latest symbol of our technological culture offers us, as other technological breakthroughs have, that sense of competence and consequent self-esteem that makes human life more than an Ozymandian footprint. With its mythical valuation based on its effectiveness in condensing human time, memory and logical processes, it cannot help but be utilized in all areas of our society, not the least or last of which is education.

But if modern technology is part of our secular religion, it must also be viewed in relation to our other values in which human relationships are primary. In these the individual is respected, his idiosyncrasies treasured, and his self-esteem which comes from a sense of belonging, participating, competence, comforting, and being comforted, are valued.

The use of tools and technology by man, as Bruner points out [1], has made it possible to amplify his powers but also modifies his social integration. I would only add that most often man has made few choices regarding his technology with awareness and in consideration of the changes in the social structure that would evolve. The effect of the automobile upon family life, morality, and the total economy and culture was never predicted nor considered in the fullest sense. In this matter, we are all historians and not planners whether we be optimistic or pessimistic in our views.

In the search to extend our competence through technology, we find that we run the risk of loving the machine and losing the man, or at least the opportunity to extend our sense of effectiveness to promote other humanistic values. I do not mean to be hung by the cliché of fear of the mechanical -- only to propose that we consider the seductiveness of technological effectiveness as the whole goal rather than a partial one. One does not need to look to history that is more than days old to view our seduction by the myth of technological warfare. Nor can we ignore the hypothesis that our technological state has made of our cities a desert environment where human beings are dehumanized bits of the scenery and desperation, isolation, and anomie are the colors of the arrid life. The culture of the hippies can be accepted as one form of protest against such a world.

It is rare, then, that public policy regarding technological change has been alert to the multiple effects upon society and its humanistic values. To be sure, we may base such policy about computer-Assisted Education solely upon the pragmatic aspects of cost-effectiveness, economics, problems of innovation, and the like. We may define our policy around such issues as individualized instruction. But it is pre-Columbian map-making not to look into the effect of technology upon social structure and humanistic values when we make our choices. Policy options cannot avoid the effect of these choices, whether they ignore them consciously or not.

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[1] Bruner, J.S., TOWARD A THEORY OF INSTRUCTION, (pg. 24), Harvard University Press, Cambridge, Massachusetts, 1966

Finally, one may re-emphasize that where the professional, educator, scientist, or psychologist has expertise in defining the possible options, the necessary choices must be made by those who see the options within a larger context of the values and with a large functional ear for those whom the decision is meant to affect.

Theories

Schools, like all social institutions, have evolved to do what the family cannot. One thing the family can do, as Bruner and a host of others point out, is to make possible the learning of preliminary or primary skills of language. It can also provide the cognitive map of the social and material environment through the dialogue among the parents and the child and his siblings. This, then, sets the framework for more intricate dialogues in which a more differentiated knowledge is acquired. The learning of a learning process as well as the content of knowledge begins at home.

Where the family cannot continue its tasks, the school does. And where the family fails to provide the opportunity to learn basic skills, the school can be extended as we have done with the Head Start Program.

It is important that in planning we keep in mind this process for we are increasingly offering education in areas where we feel the family has failed. Interestingly enough, we are excited by Computer-Assisted Education with the hope that its technology will provide what the teacher fails to do. Remedying human fallibility in small social institutions through the development of larger institutions and/or technology has been the history of this country.

But for technology to extend the abilities of man and lessen his failures it must relate meaningfully to what is inherent in man; his biological capacities and constraints and his values.

For a teacher or a computer to teach meaningfully, the process used must be based upon a knowledge of the learning process in children that is more than stimulus-response. It must be related to concepts of neurological and psychological development as well as to the inner motivations of the child for mastery and competence. We recognize that the infant can imitate sounds without acquiring the symbolic aspects of language. So, too, older children can take in information without it being the kind of knowledge that can be used by them in a new unstructured setting. The ability to use information as a new building block for other concepts, ideas, or explorations is a necessary criteria of learning. Education that does not take into account the developmental factors that influence learning, runs the risk of providing limited information without knowledge or segmented knowledge without generalizable application.

Meaningful teaching needs a base in theories of childhood development cognition, and learning, such as those of Piaget, Erikson, and Sears, to mention a few. Though educators have known about these theories, few have utilized them to provide a curriculum consistent with their wider scope. Piaget's concepts of a sequential cognitive development are rarely the underpinning for programmed instruction, and surprisingly absent from remedial curricula for the "disadvantaged child" who has been crippled by the environment which did not interact to enhance his development.

We know, too, that the process of thinking and problem solving is as important to enhance through education as is the content that is imparted. The curriculum of the New Math, Suppes' CAI, and the Socratic program at Bolt, Beranek and Newman do consider this. But we must also remember that the process by which information or skills is imparted is learned by the child, too. Children using a teletype interface of a computer or the Edison Responsive Environment learn the machine's style as well as the content and the logic programmed by the adults. Children also learn what is not programmed as they explore their environment beyond what adults anticipate. They have a need to "beat the machine," to find some way to react with the environment that is not predicted or controlled by the adults. The need to be "on top," "one up," or in control is a crucial aspect of the process of discovery. It is mentioned by programmed learning experts, but rarely used. If it is, it is done so hypocritically with a poor imitation of control offered to the child who soon learns that only a limited number of routes for exploration have been made available, and that he must restrain his ways.

It is risky for all of us to offer to others the true control of their own thoughts and behavior. As parents, we find it truly difficult to give a child the freedom to be different or idiosyncratic. For teachers with a public responsibility it is almost impossible. Even as a psychiatrist one finds it hard to allow a patient to be crazy though it may be the only way he can express his unique ideas.

Despite what it demands of adults, freedom is often what the child needs at certain times in order to learn. The opportunity to be the creative questioner and developer, and not the respondent is the equivalent of truism that when we teach we often learn more than when we are taught. Programmed instruction and the CAI now in use usually denies the child this chance. The exploratory mathematics program of B.B. & N. and some aspects of the Edison Responsive Environment System were notable exceptions among the sites that we visited.

A related bit of educational theory is to be found in Bruner's statements [2, 3], that learning should 1) free the child from automatically responding to external or internal stimuli, and 2) encourage the

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[2] Bruner, J.S., *Op. Cit.*

[3] Bruner, J.S., ON KNOWING, Harvard University Press, Cambridge, Massachusetts, 1963, pp. 131-148.

internal rewards of pleasure that arise through mastery and competence rather than from the external rewards of approval or fear of ostracism. Such inner-directedness can come only from the child's having that kind of dialogue with adults that 1) offers appropriate information in the form that he is congnitively able to utilize, 2) allows the child to utilize his information in an active and effective fashion, and 3) indicates that his effectiveness or failure is not a threat to the adult upon whom the child is still dependent in part.

It is in such aspects of learning theory that one cannot help but see the relation of theory to cultural and societal values. If we wish to have independent and flexible individuals to master the rapid changes of our technological society, we need such inner-directed people, and must educate them accordingly.

There is one other aspect to learning theory which should be mentioned before going on. If we consider Piaget's theories and Bruner's comments about the stages of learning, we can see that multisensory manipulative exploration both enactive and iconic learning as Bruner puts it are essential for the young child. Few CAI programs have this as yet; most utilize learning programs in which the child needs only the cognitive capacity for the symbolic use of language. The Brentwood program attempts it, while the REC learning center has much of it -- some on the machine and even more in its classrooms. At the University of Pittsburgh, many new computer interface devices are in experimental development that will provide a broader range of sensory activity.

The crucial point is, technological devices not only place distance between the child and his environment, but selectively edit the environment, which is an aid in structuring the input for the child. If this selection process edits out too much of his varied sensory apparatus, this may lead to effects not anticipated. My hypothesis is that the child will either use his unstimulated sensory modalities in opposition to the learning process at hand, or will not sharpen his inner processes of discrimination and selective attention. I suspect the mind can tolerate limited sensory usage in any specific sensory modality over a finite period of time before it needs to readjust the balance.

This hypothesis is not the only reason to stress the development of multisensory interfaces, but it may be worth considering.

Forms of the Learning Experience

I have discussed some of the general theories of learning which must be considered in examining the utilization of CAI. But we must recall that CAI is not the only form of teaching or learning, nor can it easily substitute for every one of these other forms. It is important to look at CAI within a spectrum of learning interactions.

Individualized and group programmed instruction, like its child, CAI, is primarily intended as an experience where the student learns by himself. Interestingly enough, in no installation does this remain true. The child at the teletype in the Stanford mathematics program is never alone in the room though he may focus on his electronic companion. He is aware of others who are with him, discusses his interaction with the computer, with others, and even compares scores with his friends. The effect that competition, scoring, and the presence of others has upon him in this special room is not considered in the program. The Hawthorne effect of a special program and the creatively interested adults who work on such a program is not only to be studied but perhaps valued without disparagement.

Perhaps all education should be a continuous "Hawthorne experience." Perhaps we can only obtain this through a never-ending series of new programs. Being new, not only to the learner but to the staff, the interaction may be kept at a vital pitch that abets learning.

Group process is an important learning form, but we do not know much about the effectiveness of an interplay between group and individual processes in a sequence that may be ordered and varied over time. Nor are we very knowledgeable about the use of groups at computer interfaces. Then there are the peer groups that evolve without adult supervision, the role of which we have yet to fully recognize in an educational process. If it were anticipated, could such a group be left alone to function through its informality or should it be formally joined to other aspects of education? The educator's ability to risk the presence of a powerful learning form that is not under his control is an important dimension to be thought about.

Peers are extraordinarily effective in teaching many aspects of social interaction; they may also play a part in the learning processes in language, arts, and mathematics. We have some knowledge about the "each-one teach-one" program that Mary Stewart has used in California to teach reading to drop-outs and that the Responsive Environment Center in Brooklyn, New York has used with high school age retarded readers. Should this concept be extended in more areas, even to the programming of the computer as the Responsive Environment Center has also done?

Other social processes are yet to be tried out. The use of complicated games by Abt and others which teach a complicated social system theory is an exciting dimension of learning as are other role-playing forms.

The Mix of Learning Forms

Of prime importance is the "mix" of learning forms that may be possible, and made available as individualized programs through computer planning. Alexander Schure's New York Institution of Technology is the best example of development along these lines. The Responsive Environment Center and Oakleaf School have also implemented this with some degree of professional awareness. Much remains to be done in this area, and the knowledge obtained from such eclectic studies should be of importance in deciding where and how to utilize CAI best.

The State of the Art and the Presence of People

Cost Effectiveness

Computer technology is obviously advancing rapidly. The use of micro-modular construction and time-sharing makes computers economically feasible today for some, tomorrow for most, the next day for all. Just how long it will be in real time till the day after tomorrow comes is a question. One suspects that the computers will be relatively inexpensive soon but that the accessories will keep the costs high. Software, long transmission lines, special interface devices, all will raise the cost like air conditioning and power brakes in cars. Nothing new or better ever costs less in our society. Our only question is -- is it worth the price? It takes a strong mind and an empty pocketbook to avoid buying the "best" which is often the most highly valued. The need for a "Consumer's Union" to help evaluate the alternatives by criteria based on specific goals is immediate, for few can truly know the cost-effectiveness of all our technology. Perhaps it may be more worthwhile to spend money to train erstwhile housewives as teachers than to buy CAI. It would be important to know.

A look at computer technology must also take into account that the development of relatively simple English-like languages for programming and use is a matter for high priority. The less one has to know to use the technological device, the more its availability and usefulness. The advantage of the Edison Responsive Environment over similar computers that attempt the same task is that it can be programmed by anyone (including a child) with minimal training.

Languages

Similarly, if the student must learn a new jargon or language to use a tool there is one more hindrance to universal use of it. What happens if a poor speller or a cognitively indifferentiated student is on the interface that demands a special language. Will he fail to utilize the computer to its fullest? Is most of the CAI available only for those with good language skills? These questions must concern us.

The Computer in Administration

On the other hand, the computer has proven its value in managerial tasks. Its role in administration of education systems is the prime and most easily recognizeable one for the next ten years. There is no doubt that it will be of intestimable value in keeping track of students and courses if it is programmed well and supported by appropriate personnel and funds. Again, the overall costs will not be lessened, but the management tasks will change.

Software

The most expensive and obviously problematic issue is software. Thus far most CAI is in the hands of those who are devising new programs. Much of this is adaptation of older forms and models of learning. Very little is new, and possible only through the computer. The B.B. & N. mathematics and some aspects of the ERE would not have been possible with a computer. If much of what is being done is adaptive, then what does CAI bring to education?

To list a few possibilities:

1. It may bring the resource of time in which more can be learned faster by a student.

2. It may bring a higher standard of quality for all, which may eliminate human fallibility but perhaps replace it with its own.

3. It may bring the capacity for ongoing evaluations and experimentations in the learning or educational process which are sorely needed.

4. It may bring the quality of non-judgmental learning into the school (if it does not give grades which the rest of the school programs use in a judgmental way as at Stanford).

5. It may force educators to re-examine their programs with or without CAI in their schools.

6. It may bring forth new ideas for learning.

7. It will give the students the sense of technology being an element of daily life -- but the TV and the car do this already.

8. It may not save money, since its total costs are high and no CAI program will simply replace other forms of teaching for less money.

9. It will not decrease the number of personnel per school. It may change the roles of those who work there, including the teachers, but innovations do not automatically cost less in personnel.

10. It may be expected to cause stress in the system as any innovation does.

11. It may or may not provide an opportunity for the expression or learning of humanistic values.

All of the above can only be educated guesses from which public policy must arise. There are few aspects of the issues enumerated that require some further thought. This is particularly true when we discuss -- using the language of System Development Corporation --"human factors".

CAI advocates say that it frees the teacher for more contact with her pupils in areas not needing rote material. Certainly the drill work of learning can be done without computers as the Oakleaf School demonstrates. If the teacher can be free to be less judgmental, more interactive in a creative way, and more effective around human issues and social processes, we will be buying this human relationship most inexpensively, since it is so hard to come by at any time.

We may be led by CAI to consider the teacher we choose and educate and hire. Since it may be possible to teach sheer information to our children via CAI and programmed instruction, we now need, as Tanner [4] points out, "behavior models". Human beings with the human capacity for and delight in growth, change and ambiguity, and the innovative are rare. How can we develop them? And what will initiate the process to develop them in our school systems? Will the need for this kind of teachers and the cost of finding and developing them be competitive with investment in CAI? And if so, how should we spend our money? Another question that may help us ponder this problem would ask: Can this education system produce the kind of teachers that we need to educate the children to be the kind of adults we would like them to be? How does CAI fit in the total mix?

I raise these issues because we must see our use of technology as not relating to "human factors", but to people. In developing programs for CAI, the necessary knowledge about people and how they think, feel and act is sometimes lost. Thus, SDC can describe setting up a computer program for counseling that will use retired army officers. Obviously, these men represent a pool of labor to be hired into civilian life -- but can an army officer who thinks in the rigid dimensions needed to operate within an organization like the army offer the best counseling to adolescents? I wonder.

I was impressed with SDC's concern for "human factors" and their lack of understanding about how apparently illogical people are. Like the IBM systems analyst described in LIFE, who could not understand why his simple and logical procedure would not be accepted by local IBM plants, SDC could not understand how to go about gaining acceptance for their new ideas in the civilian community. This raises a bothersome thought -- should we leave the development of CAI to the technologists? (Should the making of wars be left to the generals?)

This cannot help but lead us to the problem of innovations and maintenance of new programs.

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[4] Tanner, Daniel, THE MACHINE TEACHER AND THE HUMAN LEARNER, in Programs, Teachers and Machines. Bantam Books, New York, 1964

Innovation, Its Life and Hard Times

Innovations that occur in a time of stability or general satisfaction are hard put to survive without extraordinary factors. But innovations that arise in a time of many innovations have a reasonable chance of survival.

If we consider that the educational system has been a relatively stable system with few of the qualities of a "growth industry", we can see that new ideas have not been the hallmark of our schools. Sputnik, the Supreme Court decision on segregation in schools, the Poverty Program, the post-war baby boom, and finally, the Education Bill of 1965, have shaken the system awake. Education is the formalized acknowledgement and enactment of a society's culture and values, but there has always been a cultural lag between the appearance of a change in the culture and a change in the curriculum. Our specifications for the products of our schools are rarely up to date.

Given such a situation, innovations are hard put to be adopted easily. We cannot easily discuss cost-effectiveness in our educational process since we do not specify our products. Thus, as Miles has said,[5] "There are many interpersonal and organization issues subsumed under this last category of administrative and psychological cost". Miles further points out that ".....an innovation which increases personal initiative and autonomy .... is more quickly accepted".

The innovational process also depends upon the social network of support within the school system and community. The relative position of authority, acceptance as legitimate, and personality of the innovator influence the success of the process.

With such factors as we have noted contributing to the success of innovation, there is clearly the need for an awareness of the needs of human beings. The excitement generated by the development of CAI alone is not enough to make it a relevant part of the educational process in all schools.

Any policies regarding CAI must concern themselves with the social process that logically or illogically control change in our society. If CAI is felt to be a worthwhile investment for our country as determined by its educational-social value, then the social costs of its introduction and maintenance into the educational system should be estimated, along with its financial cost in hardware, software, and personnel.

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[5] Miles, Mathew. EDUCATIONAL INNOVATION, SOME GENERALIZATIONS, in Meierhenry (Ed) Media and Educational Innovation, University of Nebraska Press, 1964.

Last Words

I question whether CAI will measure up to the extent of its advocates' predictions. With certain exceptions, the cost in both human and financial terms appears too high at present. Such specialized technology and programs as the ERE or BB&N's mathematics may now be worth a major investment. It may be a more reasonable "trade off", to "purchase" better teachers and more flexible programmed learning systems and computer assisted management than to buy CAI in its present form. Nevertheless, CAI should be supported experimentally for two years without utilization in large school systems. When the whole educational system is more open to innovations it may have matured for use in appropriate contexts. But until the day after tomorrow, most CAI appears to me to be an interesting tool to aid in the study of learning processes.

In the finite world we live in, where all things are possible, few are probable, and damned few a necessity, we still need to attend to the necessities of education. To me this means to provide the opportunities for the individual to belong to a socially valued group, and develop true self-esteem. CAI does not appear to deserve the highest priority in achieving that goal.

Charles Thomsen views the nature and potential of CAI through the eyes of an architect. In this article, he considers the role of architecture in resolving not the apportionment of individuals in space, but the relationship of the goals of education and of the individual to the better planning of the new educational technology. With an understanding of psychology, the social system, and the practical arts of communication and traffic management, he projects the consequences of that technology and diverse possibilities for the reorganization of our educational milieu.

COMPUTER AIDED INSTRUCTION

Charles B. Thomsen

Introduction

In a paper dealing with the future, there is a powerful desire to hedge every statement. The future is viewed through an opaque crystal ball; to predict is a treacherous undertaking. "The future lies ahead." (Mort Sahl)

But there are probabilities which make sense. So I will put down, at this point in time, what makes sense to me, trust the readers to assign the margins of error, and the future to determine the mistakes. As a "summary in advance," the following statements are the fundamental points to be made throughout the paper.

1. Computer Aided Instruction will be helpful as an instructional device, but it will be far more important as a device to reach new groups of people. The most valuable and far reaching effects of CAI will be felt outside existing formal structures of education. Continuing education and professional updating may all become a full-blown reality, and education may become recreational as well as instructional. So inevitably, CAI will increase as a mode of instruction. However, changes within our existing educational systems will not be as important as the new educational systems which will develop. The new programs will reach large groups of people who are now overlooked by present systems.

2. The first of these groups to be reached will be the mature, well-educated, productively-engaged professionals who continue to be interested in learning. Professionals, as a group, will be quick to use CAI effectively because (a) they can afford it, (b) they need it, and (c) they are adequately motivated to respond to self-actuating instruction. Less privileged groups of people, who perhaps have even greater needs for CAI, will be reached after the progessional groups have supported initial development.

3. One of CAI's assets is that small pieces of a learning institution can be scattered throughout a community requiring no centralized architecture. But wherever individual instruction is centralized, architects and educators will need to consciously create social interchange using architecture as their tool. When they do, the planned result will probably be much better than the social structures in today's schools which are usually an accidental by-product of other structures.

4. Programmed instruction must find teaching techniques which are sympathetic with learning motivations. Curiosity, the satisfaction of grasping new concepts, individual differences in methods of search, and the pleasure of exploring for information are all emotional drives which cannot be restricted by narrow programs and rigid channels of instruction. To provide intellectual elbow room within CAI will be educators' most difficult challenge.

Who's Going To Pay?

"Can we afford CAI?" is not the right question. If CAI has value, the question is, "How can we afford CAI?", or even better, "Who can now afford CAI?"

As costs for CAI continue to decrease, the answer to these questions will change. However, there are already possibilities for profit making or break-even applications.

This country's professionals -- architects, engineers, lawyers, doctors, and scientists -- have only limited time after graduation until their education becomes obsolete. The half-life of a degree is getting shorter, and many professionals are actively seeking channels for new knowledge. No longer can a college graduate spend a lifetime practicing techniques he learned in school. His education must be continuously updated.

As a rule, professionals are well motivated, reasonably intelligent, and have incomes which are adequate for increased educational needs. However, they follow busy schedules and cannot easily commit themselves to strict class routines, nor spend time commuting to class. Their instruction needs to be handy and on tap at short notice.

CAI not only solves these problems, but it is also within the economic grasp of professionals. For example, Caudill Rowlett Scott's 1130 computer (a complete system) costs only $8.00 an hour net (a time-sharing terminal hooked to a 7044 in New York City costs $300 a month, plus $11.00 per hour). Professional tutors often charge $15 to $20 per hour.

It is doubtful that professionals will own their own terminals. More likely, multi-purpose terminals will be placed in locations where they may be easily reached by any number of people.

But the hardware costs are only the first hurdle. Development of proper software is a major problem. Professionals who can afford CAI characteristically would be impatient with mediocre programs. The proper internal organization to implement this new educational thrust is an even greater difficulty. However, given good software and management, individual instruction for professionals and executives is a surefire success. Operating costs are no problem. Once the initial massive development is implemented, costs will plunge to where the larger, low-income groups -- in far greater need of education -- may afford CAI. Hopefully, during the expensive stages, grants and subsidies will support research thrusts which will speed CAI to all groups.

While professionals may well afford $20 an hour for individual instruction, what about CAI in the public schools? How do you place a dollar value on increased educational benefits? On the surface, there is a strong feeling in the United States that if something has value, somehow we will find a way to finance it. This is true, but the questions are no less valid; they are simply difficult to handle. There are two very distinct ways to consider the cost/benefits of CAI.

There is the approach that a school board or a superintendent must take. With set budgets, there is rarely enough money to cover all the pressing needs. To add CAI would require convincing arguments and the deletion of other items. So eventually, the cost/benefits issue must be faced. The comparison is inevitable. And for the moment, at the public school level, that comparison cannot help but be unfavorable for CAI.

But there is another consideration. Obviously, a better educated population will produce more. The questions then become, "What is the return from $100 spent on CAI research? Is it $150, $200, or $2,000?" Can we assume that an educational expense is an investment in our nation's capacity: If we do, these other questions are appropriate for foundations and for local, state and national granting agencies with funds available for this kind of long-range investment. But these agencies also demand comparative evaluation. However, this time, the evaluation must consider cost changes that will occur over the next few years. Certainly, the cost of CAI will decrease. But will it decrease to a point that public schools will find it a practical method of instruction? For several reasons, I way yes. It is inevitable.

1. During the last ten years, the cost of computation has decreased several orders of magnitude. Present indications are for continued, and even accelerated reductions.

2. School systems are big businesses. They already use computers for management and accounting. As software develops to make time sharing more reliable and less expensive, schools will lease larger computers at minimum premiums and use them in educational processes too.

3. Educational systems are staffed by increasing numbers of young people graduating from institutions where computer savvy is becoming as common as the frug. While teacher-training institutions have often been slow to grasp this new tool, its use as a measuring and administrative device will soon make it universal through all disciplines. It will be only natural for the generation educated during the "scientific revolution" to apply the computer as an instructional tool.

Less inevitable is the application of CAI in places where it is most needed -- outside our existing schools. The easiest mistake will be to analyze blindly this instructional opportunity only within the concepts of existing education structures. And despite the fact that professionals can pay for CAI, the hardest objective will be to create the new educational structures to bring it to them.

Wide Corridors of Instruction

An early charge against the computer (not only in education) was that its influence would be de-humanizing. The spectre of the lazy sorcerer's apprentice, who harnesses mysterious forces to assist him, and is nearly overcome in the process, haunts us as a society. Some people are concerned that the machine would organize our lives in a machinery ritual. But instead, its use has simply made more clear what it means to be human. CAI offers more evidence.

First, CAI supports only a secondary educational objective -- that of teaching "things". The primary objective must always be to convey attitudes of dignity, inquiry, curiosity, honesty and integrity. Attitudes are not taught. They are acquired from other people or from art. Therefore, if CAI is able to instruct students about things, teachers may convey attitudes through personal relationships with students. Administrations will be able to place greater stress on these objectives.

Secondly, each student may be administered and taught as an individual. The computer's ease of maintaining student records means that now a student's performance may be recorded, retrieved, and reported more frequently and on an individual basis. This frequent reporting in itself is a powerful educational technique. The fact that a student's performance can be quickly measured means that it can also be quickly affected and properly guided.

But there are also problems. The computer can be a trap for undisciplined users. Its very capability can destroy its power. Line printers now run 1,000 lines a minute. The fact that more than the most pertinent information is readily available encourages us to produce it, but this bulk of output can also mask the essential facts with unessential, mere "interesting" sidelights.

Also, the way in which we can tolerate error is vastly different with a computer. A computer requires far more precision than a man.

A man is often able to detect a correct intention if the error is only minor. With a computer, one can anticipate some errors, but if the answer to a question is as simple as the word "Shakespear", and if you have to figure up all 500 variations of the way to misspell the word so that you can accept a slight misspelling as correct, the programming task is too clumsy.

It is also possible to make serious human errors of another kind, particularly with systems requiring absolute completeness. For example, it is terribly presumptuous for an educator always to define terminal and intermediate objectives in a course of study. Students, particularly the good ones, are capable of selecting their own objectives, often beyoud what a teacher might set. We will seriously limit a student's ability to learn if we define his objectives too precisely instead of spreading before him a host of information from which he can select what most interests him.

One of CAI's most compelling promises is in linking enormous information retrieval capabilities. Information search characteristics in an open-ended "program for browsing" will be possible. Rather than having defined specific objectives, a student could let his curiosity range and learn just as an individual browsing through a library may discover exciting and useful knowledge. We might learn as the action painter who predicates his next strokes upon the accidents and discoveries of the last.

The computer will also affect our approach to art. The precision of sequential logic has always been associated with discovery in science. But despite fears that this same formal logic may inhibit artistic breakthroughs, new aesthetics of great order and complexity may be found. The structure of a dandelion has great order, and the sum of the cross-sectional area of two branches of a tree equals the area of the single branch from which they grew. The scientist and the artist have similar objectives: Science is the search for truth; Art is the expression of truth. It is not unlikely that the same tool will serve both.

Architecture as a Social Art

The school as a building type is a newcomer on the American landscape. Today's school architecture is no more than 20 years old. In early American days, our schools, churches and barns all looked alike. The only distinguishing feature was the steeple. Schools had a bell, churches a taller tower, and barns simply a little cupola with a weather vane mounted on top.

Later, schools, courthouses, and hospitals looked alike -- two-story masonry beasts that expressed more concern for propriety in public service institutions than attention to a viable learning environment.

Since 1945, schools have emerged as a building type, along with high-rise office buildings and promised to be the American contribution to the history of architecture.

The process of organizing a school is simple. An individual is put in a box with other individuals. The box is then placed in a larger box. The result comes in many varieties, but the prototype is a one or two-story dominant classroom wing made up of repetitive classroom boxed placed on either side of a double-loaded corridor. Exterior walls have continuous glass above a desk height panel below, made either of colored porcelain or brick. Associated with the wings are a few larger boxes for auditoriums, gymnasiums and multi-purpose rooms.

This prototype of only 20 years is failing. New educational demands such as team teaching and Trump planning of variable classrooms are forcing its premature death. CAI may be the coup de grace. The repetitious student box may go completely and with it the fundamental social structure it provided. And individualized programmed instruction provides no inherent structure of its own. But educators and their architects will be free to search for the very best -- unencumbered by the classroom box.

So now with the educational structure finally broken down to the individual, ways must be found to fit it together again. Indeed, the kind or research that has gone into establishing social units in dormitories would then be appropriate within schools. A social structure of a school would be developed from a hierarchy of groups from the individual to the total, rather than a regiment of repetitious classrooms.

Architecture will be the educator's chief tool in creating these new societies. The bull session as an educational objective, chance meetings between students of different disciplines, and comfortable locations where student-faculty interchange can occur on a semi-formal level will be subjects of vital interest to new school educators and their architects. The buildings may then be planned to be sympathetic to these objectives. Tomorrow's educators likely will have trouble building space for these activities. Communities may balk at paying for "bull session areas" just as they now complain about archery ranges and modern dance studios.

And to compound these problems, costs of building schools will rise. Technological innovations continue to increase, and the rate of change in educational facilities will increase with them. The need for flexibility will grow, and flexibility costs money. For example, the conduit systems to meet the demand for growing communication and power demands increase costs, but also long-span structures and modular planning for convertibility will also drive up costs. However, other economies may result. In cities, the traditional three-story prototype school covering large pieces of land at last may become a tall building rising above the surrounding commercial structures to claim its share of sun and sky. In the past, high-rise educational facilities have not been economically feasible. The elevator systems become far too costly if designed to handle floods of students at class breaks. With no set class breaks, fewer elevators could handle the steady trickle, and high-rise schools would be possible, saving costly land for green play fields.

Circulation within educational facilities may be minimized. At the university level, it would no longer be necessary for a student to circulate among the architectural, chemistry, math and English buildings. Instead, he simply may dial different courses at his console and stay in a fixed location. There may no longer be any need for a "discipline-oriented" building. This means that a student's circulation primarily will be from his home to the school, with minimum circulation needed within the school. This could be a serious loss, as it would eliminate the social mix generated from chance contact peers. Without careful planning, an institution devoted entirely to computer aided instruction might become an academic shopping center with large parking lots available at the perimeters so that students may park closest to their carrels. An internal social structure would be non-existent.

And in some institutions already under construction, faculties are experimenting with curricula of total programmed individual instruction. This fact points up a strange paradox. Without the social values of an educational institution, and if the entire curriculum were based on indivudual instruction, there would be no need for a centralized facility. No longer would campus facilities be needed. If a student can dial any course available from one console, then there is no need to build a complex of buildings. There is only a need for a central resource area somewhere in a region which can disperse information over wires to scattered remote stations.

Indeed, CAI does not need a school building. Learning stations could be in a supermarket, an airport, or could occupy a floor of a high-rise office building. There could be facilities on computer trains, in local city halls, or perhaps in the general store at the intersection of two rural highways. But just as a school could be fragmented, it could also get terribly large. At the moment, there is a physical restraint on the size of colleges, based on the maximum walking distance within the ten-minute class break. If this ten-minute class break no longer exists, that particular restraint disapears also.

In conventional school, the path of the student is to arrive, to move to several classrooms, through the Union, library, and laboratories. The simple fact of circulation has tremendous social implications. In an institution devoted entirely to programmed instruction, that circulation would be non-existent. The carrel, not the classroom, becomes the major architectural element, and circulation from carrel to carrel is unimportant and unnecessary. The school building itself becomes a super learning machine, specifically designed to provide for instruction.

The architectural form becomes a manifestation of individualization, and social structure must be added as a conscious and deliberate act.

The architecture of the carrel and its immediate surroundings becomes vitally important. If it is true that communication may be reinforced with additional media and additional impingement of the senses, then the programmed instruction course becomes more effective with a higher level of instrumentation. For instance, do word patterns on paper become reinforced with graphic illustration and then more reinforced with audio-stimulus: Should CAI seek to orchestrate as many media as possible with its objectives? -- to immerse a student in a total environment of learning where he is at the center of a completely specialized world: This, indeed, would be a job, not only for educators and psychologists, but also for architects.

While efforts are under way to create complete educational institutions whose sole form of instruction is individualized programmed instruction, the majority of schools of the future surely will evolve their programs -- keeping the traditional educational techniques which are most useful. And so the architecture then will also retain many of the forms of the past. But CAI, like team teaching and Trump plans for variable size classrooms, will be another vital attack on the banality of the 24-student box endlessly and monotonously repeated along a double-loaded corricor. The result will be greater freedom for educators and their architects to shape their schools for the higher aspirations of society. But high degrees of capability must be intimately associated with this freedom, for the new opportunities carry heavy responsibilities.

Education's Broader Reach

In 1840, Horace Mann said, "The object of the common school is to give every child a free, straight, solid pathway by which he can walk directly up from the ignorance of an infant to a knowledge of the primary duties of a man."

Bill Caudill, of our firm, has challenged this. He says,

> "Today is not the day of Horace Mann, nor of the horse and buggy. It is not enough for education to develop a child to have a knowledge of the primary duties of a man. The principles of Horace Mann are sound. And today's education structure is also sound. It just does not go far enough . . . We need a new structure. And to get it, we need a 20th-Century Horace Mann who will shake us out of our horse-and-buggy complacency by saying something like this and making us believe it: The object of education is to give every person, at every stage on his pathway from infancy to old age, a chance to develop

> fully the skills, to achieve the wisdom, and to preserve the wish to live abundantly a life which will be rewarding to himself and will contribute to a strong free nation."*

There is far too much concern about replacing cherished educational processes with new fangled computer-aided instruction. It will be an addition, not a replacement. Perhaps some existing educational modes will atrophy, but the educational structure as a whole will grow from CAI's ability to reach new groups of people.

A fact, seldom touted by the computer salesman, is that in most organizations, computer processes have added new functions. Rarely, have computers directly replaced existing functions with more economical processes. Eventually, old functions are absorbed, but rarely is there a one-to-one replacement.

Computers are used in organizations with growth potential. Education has this potential. Not only is the country's population increasing, but whole new educational structures are developing for new kinds of people seeking education.

While professionals may be the first to afford CAI, they certainly are not the only group needing to update their education. Among the ranks of the unemployed are many who have been displaced because of technological changes in industry. With new kinds of training, these people can again work productively. Civic leaders and businessmen want to learn new techniques. A child prodigy may find his school curriculum lacks sufficient enrichment and takes new courses. A farmer may look for scientific applications such as fertilization techniques. A high school teacher may work towards a Masters Degree. All these requirements can be met at the same institution. To reach these individuals, a very small institution might have several thousand courses on tap.

Opportunities for higher education should be provided for all, rather than just the few who can commit regular amounts of time to a routine class schedule. Ideally, students should not have to leave the region of an established home or job. New educational systems must accept the difficult assignment of designing curricula to suit the needs of a wide range of human capacities, interests, aptitudes and levels of intelligence.

Technological innovations in education inevitably make these new educational missions possible. Technological innovations also create new forms of activity. If innovations magnify human capabilities, the effects can be dramatic. If that magnification is by an order of magnitude, it may effect our entire social structure. Several examples bear this out.

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* THE MOST IMPORTANT NUMBER IS ONE; William W. Caudill; Investigation No. 11, December 1964; Caudill Rowlett Scott.

Prior to 1900, man could move at 4 and 5 miles an hour, walking or riding in a carriage. The early Industrial Revolution boosted that speed to 40 or 50 miles per hour, and a fundamental social change occurred. And the next boost to 400 or 500 miles per hour in jet travel brought another fundamental change.

Amplification of man's strength has also affected society. Before the Industrial Revolution, we could harness animals and produce 4 or 5 horsepower. During the early twentieth century, we were able to magnify this to 40 or 50 horsepower. Now we are dealing in magnitudes of power 10 and 100 times that. Each additional step caused basic and extensive reorganization throughout all sectors of our society.

Now, our ability to process information has jumped not one order of magnitude, but several in the course of eight to ten years. The sociological implications at this point in time are simply unpredictable. Surely this leap will affect our educational structures.

"Who will do the software for computer aided instruction?" We have trouble answering this question because we conceive the answer in terms of today's structures. We question the publisher's credentials, but have trouble imagining the matronly teacher with ruler in one hand and Fortran coding pad in the other.

There is no reason to believe that producing software for education will be more difficult than for other industries. Just as bright young engineers or accountants have done software for their particular disciplines, there will be a generation of bright young educators developing software for their fields. Just as the architect or engineer is no longer someone who sits at a drafting board operating a T-square and a triangle, an educator may no longer be a person standing at a blackboard with chalk in hand. He probably won't even be in school.

We would make a monumental blunder if we assumed that computer aided instruction is limited to the physical boundaries of existing educational institutions. However, new techniques demand new structures and present organizational challenges which are greater than the technical challenge. Unfortunately, our democracy is quicker to support the development of new technology than to concoct the organization systems to effectively engage them. Technological innovations stagnate without effective management. We can safely bet that the organizational problems of applying CAI will hinder its development more than the technical hurdles.

Credits

Pages 3, 4, 7, 8, 10, 12, 13, 15, 17. THE MOST IMPORTANT NUMBER IS ONE: William W. Caudill; Investigation No. 11, December, 1964; Caudill Rowlett Scott.

In her consideration of "The Knowledge Machine" Elizabeth Wilson demonstrates the breadth of her understanding of Education and Society. As an educator she perceives both the promise and the problems of the computer. Her article ranges from the specifics of curriculum development and costs to the role of education in society. Dr. Wilson emphasizes application of the computer for individualization of instruction that differs from the contemporary view of an isolated individual instruction. Her suggestions direct us to a process of innovation and application based on an understanding of education, CAI, and the individual in society.

THE KNOWLEDGE MACHINE

Reflections on the School and the Computer

Elizabeth Wilson

Prelude

> "Dread is the possibility of freedom. Only this dread is by aid of faith absolutely educative, laying bare as it does all finite aims and discovering all their deceptions.... He who is educated by dread is educated by possibility, and only the man who is educated by possibility is educated in accordance with his infinity." 1.

What have these sombre words of Soren Kierkegaard to do with the use of the computer as a tutor? What possible relevance can the thoughts of a long-dead Danish preacher and the father of existentialism have for the schools and the educational processes of tomorrow?

At first glance, any relationship seems very far fetched. Perhaps so. But the underlying theme of this paper is that Kierkegaard's ideas make an excellent backdrop for an examination of some of the major issues which face educational policy makers in the next two decades. Indeed, we suggest that the key phrases are dread, possibility of freedom, and educated by possibility.

The Traveling Seminar

Personal Biases and Impressions

Up until May of 1967, my contact with computer-assisted-instruction or what I am calling "The Knowledge Machine" was, by and large, indirect

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1. Soren Kierkegaard, The Concept of Dread. Translated by Walter Lowrie. (Princeton: Princeton University Press), p. 139.

and peripheral. As a school teacher and administrator in and out of this country for many years, and, more recently, as a specialist in the design, building, and evaluation of curriculum in a large public school system, I had attempted to keep up with the professional non-technical literature on the subject. Moreover in our school system we have a history of considerable experience with programmed learning. At one point we tried to build some programs of our own, tailored to local specifications. Some five years ago, we did some systematic evaluations of several representative programs in action at different levels of instruction. This school system, moreover, is familiar with the computer as a processor of actuarial, financial, test and research data. An IBM 1400-series will be added. In fact, the school system is currently in process of planning a pilot project designed to bridge the gap between CAI technology and the schools' capacity to understand and use this new tool.

My major personal interests and professional concerns, however, have been to keep up with the Curriculum Reform Movement, and to develop within the school system a rational framework whereby we could translate existing curriculum theory into everyday classroom practice. This effort has had three major thrusts, namely; (1) the thrashing out of behavioral objectives in all major subject offerings in the curriculum (K-12); (2) the building of operational models which order the decision-making process in curriculum and instruction within the school system; and (3) the study of the dynamics of curriculum change in a large school system. These activities are not unrelated to computer-assisted-instruction, but they are not directly on target. In short, though I am a relatively sophisticated educator in this respect, I cannot qualify as an expert in this technology nor in its application to learning. To become a member of "Margolin's Mission" or, more seriously, a member of the George Washington University traveling seminar was, therefore, a real opportunity for me to learn something. Learn something I did. What follows are impressions -- subjective judgments regarding a kaleidoscope of observations and events superimposed upon the kind of interest and experience I brought with me.

An immediate and pervasive impression is the power of this new tool for learning. The computer, I believe, does have the eventual potential its promoters are selling. Already operational is its capacity for storing, categorizing, and retrieving knowledge in a manner unimagined two decades ago. And there seems to be little doubt that these capacities will increase in efficiency and in complexity in the near future. Nor is there much doubt in my mind that present high costs will soon be a statistic in computer history. Within the next generation I suspect the machine can be within the economic orbit of every student in the nation.

Even more compelling are the more sophisticated capabilities of the machine. I am convinced that it can and will be adapted for such educational purposes as tutorial dialogue, simulation, for use as a problem-solving and retrieval laboratory, and for examination of complex problems in the social sciences. As such possibilities develop, the machine should be able to absorb large pieces of the problem which has been the bugaboo of mass education, namely the individualization of instruction. Equally important, though not nearly so popular, is the logical and analytic quality of thinking the computer demands of its users, whether those individuals be students or teachers or behavioral scientists or politicians. The machine forces conscious conceptualization of problems. Thus the teacher wishing to use the computer to assist in the diagnosis of student's learning difficulties is pushed toward further analysis himself. Or the administrator looking to the computer for help in solving scheduling or staffing problems may well get feedback into the strengths and weaknesses, not only of the issue under scrutiny, but also of his own processes of analysis and conceptualization. In other words, as one of our hosts in Cambridge noted, "the machine looks over your shoulder as you work with it." Such a push toward analytical awareness of behavioral and social issues may well be an unexpected and powerful by-product of further investigation of computer-assisted-instruction.

At the same time that I was impressed by the educative possibilities presented by the computer, I was depressed by the state of the art. That is to say, I was depressed not by the technology, nor by the ingenious language being invented to make the computer work in the field of education, but by the limited and embryonic nature of the programs currently under development and field testing. They tend to be little more than a marriage between the computer and well ordered programmed instruction. The best developed of these programs seem to be in mathematics, in beginning reading instruction, and in foreign languages. These subjects admittedly lend themselves to logical, sequential development better than other disciplines. Admittedly also, the building and experimental tryout of a variety of good programs could materially improve the individualization and quality of learning of these skills. But the programs in use are hardly revolutionary in quality. The development of a variety of interfaces is embryonic, and exploitation of the machine's potential is narrow, to say the least. To be sure, experimentation in types of interfaces is under way, but I saw little evidence of its being very far beyond the drawing board. There is also little evidence that more than a handful of schools is using existing computers beyond the simplest actuarial level, for example, in the building of individual schedules for students, or in studies of pupil and teacher data for instructional purposes.

Perhaps the most disturbing feature of the live operations visited was the seeming dependence upon the computer program alone rather than upon examination of the potential of the computer as one of a series of instructional modes and materials i.e., films, dramatic play, art and music materials, TV, etc. This observation hit me the hardest at Oakleaf School. There I felt that programmed instruction had almost engulfed the total curriculum. No doubt, this is an exaggeration, but I missed the color, warmth, and human interplay of a variety of media, activities, areas of investigation, and personalities. One felt they had out-skinnered Skinner and that the results, though solid, seemed sanitary, well disciplined, and dull. One wonders what will happen to this school when the enthusiastic young researchers leave, and when the aura of the Hawthorne effect has worn off.

Such comments are not intended to undermine the efforts at Stanford and at Pittsburgh. It is essential that such important research and development proceed under the guidance of the innovative leadership both enterprises enjoy. The dangers are not in what is going on, but in the readiness of the press to give the impression that CAI presents a single simple solution to most of the problems faced by the school. The press implies that the heavy investments of Wall Street and of giant new industry have rounded up the brains of the nation, have produced quality programs in quantity, and are ready now to move with dispatch into the schools. It was a real shock to discover how crude and primitive the programs actually are, and how far from large-scale integration into the schools or into the educative process in general.

Another persistent impression I brought away with me was the artificiality and impersonality of this medium of instruction. This comment does not deny the possibility of computer responsiveness to individual needs. But such responsiveness is pre-packaged and de-humanized. These characteristics, I contend, will continue to exist, no matter how much more sophisticated and sensitive the modes of instruction and interfaces become in the future. I found attempts of programers to be cute and personal somehow offensive; in short, fake. It is the same reaction I have to a canned telephone answering service. Efficient it may be, but personal, no. I resent attempts to gild the lily. The fact that the medium is abstract and is mechanical does not detract from its usefulness. But if its promoters insist upon building in false characteristics, they may find themselves with a generation of children who cannot distinguish between a man-made and a natural environment.

In the same vein of discontent, I wonder whether the "Compleat Memory of Mankind" which computer storage and retrieval systems make a real possibility is always a desirable commodity. In psychological terms, is total recall always useful? Or are some kinds of forgetting functional both emotionally and intellectually? The thought that all bits and pieces of discrete factual knowledge can be forever preserved for posterity gives me the creeps. Perhaps we would be better off if we occasionally had to clean house and throw some pieces away.

And finally, I react to the knowledge machine with considerable foreboding. These feelings are reflections of my respect for its potential power. Such power means that all peoples can indeed have access to the funded knowledge of mankind, and, further, that they can acquire this knowledge at their own rates of learning without teachers. An enormous amount of drudgery and boredom of both teaching and learning can be assumed by the machine. But with this potential comes also the brooding spectre of control and invasion of privacy. Education has always been a tool in the hands of a dictator. The computer-tutor simply makes education easier for Big Brother to control. It matters little whether his name is Hitler, or Hirohito, or the General Educational Corporation.

The School of the Eighties

It is probably easier to imagine the impact of the computer twenty years from now than it is to project its effect tomorrow. Let us therefore look first at the outlines of the last two decades of the twentieth century before considering the more immediate implications of computer-assisted-instruction.

Marshall McLuhan and George B. Leonard (in a recent issue of Look magazine)1. visualize an educational Utopia. According to these prophets, "schooling as we now know it may be only a memory."2. They foresee computers with the capacity to understand both speech and writing, making "all of mankind's factual knowledge available to students everywhere in a matter of minutes or seconds."3. Computers as part of electronic learning systems containing television and sophisticated programmed materials will help tomorrow's student become "an explorer, a researcher, a huntsman who ranges through the new educational world of electronic circuitry and heightened human interaction just as the tribal huntsman ranged the wilds."4.

The McLuhan-Leonard vision assumes that standardization mass education will be a thing of the past, discarded along with the material mass-production line with which it has run parallel. It takes for granted that tomorrow's teachers will have adjusted to a new role in a schoolroom which is literally the world. It expects that "fragmentation, specialization and sameness will be replaced by wholeness, diversity and, above all, a deep involvement."5. Mankind can then truly be "educated by possibility. . . in accordance with his infinity," as Kierkegaard had hoped.

But Kierkegaard, we remember, linked educational possibility with dread. And dread is the mood we tend to associate with other distinguished contemporary prophets like Aldous Huxley, George Orwell, and more recently Leo Szilard.6. These men were equally fascinated by the future and, if not by computers per se, at least by technology and by communication. They were, however, painfully aware of the sombre possibilities of the political control of education and of the slow death of the humane values we now cherish. They had a healthy fear of man's lack of self control and ability to misuse his technological advances.

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1. Marshall McLuhan and George B. Leonard, "The Future of Education: The Class of 1989," Look, February 21, 1967.

2, 3, 4, 5. Ibid

6. Leo Szilard, The Voice of the Dolphins (New York: Simon and Schuster, 1961)

The predictions of these two sets of prophets are poles apart. Which of them has more validity for the future? Which is more probable?

I would like to believe that McLuhan and Leonard are not dealing with dreams -- that future educational patterns can break out of old molds -- that the school of tomorrow can in fact be "more concerned with training the senses and perceptions than with stuffing brains." 1. But I have lived a long time with education, both in its formal existence in places called schools, and in its informal manifestations in the socialization process. This experience documents the layers of conservatism which exist within the educative establishment, within the local communities whose values the schools reflect, and within the local and national political structure. Conventional wisdom regarding the task of the school dies hard.

We must remember that the function of the school has evolved slowly over literally thousands of years. In simple societies, where learning to become adult members of the society is relatively uncomplicated, educational arrangements tend to be informal. They are handled by the family, by elders and chief priests, and by peer groups, through ceremonies, rituals, and participation in the economic work of the groups. When a society becomes more complex, and especially when there grows up a heritage of written symbols, specialized agencies or schools appeared. A particular group of people known as teachers were given the task of transmitting the more complicated, symbolic, and abstract aspects of the culture. Thus the schools became the formal institutions which augmented the educational function of the family and of the religious and economic institutions of the society. Furthermore, says an expert in comparative education:

> "When a formal system of education is organized, society selects from all those cultural experiences to which the child is exposed those aspects of its culture which it regards as most valuable for its own coherence and survival." 2.

In our society, the conscious task of the schools has traditionally been an intellectual one. The "major" subjects of the curriculum have been related to the learning of symbols, i.e. language (native and foreign, written and spoken) and mathematics, and to "factual," data-collecting subjects, i.e., history and the social sciences and science. By and large, these subjects were taught and learned by rote. The progressive education movement of the twenties and thirties abortively attempted to bring higher levels of cognition into the process. The current Curriculum Reform Movement with its emphasis upon the "structure of the disciplines" and the "scholar's method of inquiry" is the second

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1. McLuhan and Leonard, op. cit.
2. I. M. Kandel, "The Transmission of Culture: Education as an Instrument of National Policy," in Conflicts of Power in Modern Culture, Symposium of the Conference on Science, Philosophy and Religion (New York: Harpers, 1948), p. 213.

thrust of this century to help the schools breed inquiring minds and to help students learn how to learn.

The idea that the primary function of the school is to teach the basic skills and to acquaint the student with the funded knowledge of mankind has a long history both in theory and in practice. It is one which I have espoused since the beginning of my career and one which I will abandon with reluctance. But if McLuhan and the other experts 1. are correct about the scope and speed of the electronic revolution already on our doorsteps, then the whole concept of the function of the school in our society needs massive re-examination.

According to my best judgment, the first selection of the "standard" curriculum to be absorbed by electronic multi-media will be the skills of language and mathematics -- those subjects which can be logically and sequentially programmed. Next will come what one scholar has called the "empirics," that is, science and the social sciences.

When that curricular absorption happens, what then will be the function of the school? To prepare students for vocations? To concentrate on the "soft" subjects like the fine arts, recreation, social and moral education? To use the knowledge acquired? To become a baby sitter?

The vocational function of the school seems less and less likely to be prominent in the year 1985. The first reason for this phenomenom has to do with swift and wide-spread change in the world of work. Specific vocational preparation will need to be done on the job, if at all. Actually, this situation already obtains. A second reason relates to the need of tomorrow's worker to be flexible, and hence to concentrate on the basic skills and concepts which will help him learn how to learn. A third reason suggests a revolutionary change in attitudes toward work -- the death of the Protestant work ethic, if you will, and concurrently a shift from concentration on products to a concentration on services and leisure time activities.

If vocational and professional training are increasingly accomplished through internships in the "real" world, the "school", if it continues to exist at all, is left with what are now considered "minor subjects" in the explicit curriculum and with a great deal of what we educators call the implicit and effective curriculum. By implicit curriculum here we mean the social system of the institution -- those potent and seldom conscious factors by which institutions mold the young. For example look at the Americanization of hordes of first and second generation immigrant children, or, more recently, at the enhancement of adolescent peer culture by the schools. By the effective curriculum, we mean the values and attitudes that are absorbed from the climate and the person-to-person contacts created by an institution. And we also mean the "soft" and controversial elements of curriculum which historically were assumed by the family or by religious and social agencies. Examples of this kind of "soft" curriculum are sex education, driver

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1. Vide, The Electronic Revolution, a special issue of The American Scholar, Spring 1966, Vol. 35, No. 2.

training, race relations, and guidance in self understanding.

Another possibility is that the school as an institution will cease to exist. If its primary intellectual functions can be performed by electronic media, then there is little need for the institution in its traditional sense. Rather, other social agencies could divide up the "frill" curricula left, and the schools as we know them could be dissolved.

This possibility, however, seems unlikely. In the first place, despite the press of the basic education movement for the schools to go back to the three R's and cut out frills, and despite the return to the scholarly disciplines characterized by this decade's Curriculum Reform Movement, the public has more and more looked to the schools to solve its social as well as its intellectual problems. Thus the schools have been asked to take on the race and poverty problems of Inner City and the sex and delinquency problems of Suburbia. The school is seen more and more in loco parentis -- a place that is really responsible for the socialization process of the young and for the transmission of middle class morality.

It is probably time that the public faced up to what it has been asking of the schools. Perhaps the school of tomorrow should model itself upon the Israeli kibbutz, assuming the basic effective educative function of the family, when that does not exist, and assisting parents in a modern version of the extended family of simple times and cultures. The school might also serve as the coordinator and integrator of a variety of educational agencies outside the school like fine arts centers, or laboratory-work centers sponsored and manned by industry and the professions, or recreational centers and camps, or multi-media centers where the "knowledge machine" would be available.

This version of the school of 1985 has elements in common with that of McLuhan and Leonard, with that of two young Harvard professors, Fred Newmann and Donald Oliver,1. and with that of Peter Peterson, President of Bell and Howell Company 2. There are many others. The point is not how many versions but how radical. For radical the future schools will need to be if they are to absorb rather than be absorbed by the computer.

Any of these projections are light years ahead of present day conventional wisdom about the educational process, whether that wisdom is housed within the educational establishment or within the public-political domain. The projections, furthermore, are based not only upon the electronic revolution, but also upon some educated guesses about the effects of such phenomena as the "pill", megalopolis, and growing leisure time; upon institutions like the family, the church, and the

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1. Fred Newmann and Donald Oliver, "Education and Community," Harvard Educational Review, Volume 37, Number 1, 1967.
2. Peter G. Peterson, the Class of 1984...Where Is It Going?" Keynote Address National Conference of State Legislators, December 4, 1966.

government. All these subjects are emotional dynamite. The public would prefer not to examine them too closely. Yet they are all part of the whole, as is an embryonic new morality which is now only a small cloud on the horizon. The task ahead will be far from simple. We will do well to keep in mind Toynbee's comment that:

> "... every historical-culture pattern is an organic whole in which all the parts are interdependent, so that if any part is prized out of its setting, both the isolated part and the mutilated whole behave differently from their behavior when the pattern is intact."1.

Needed Studies and Researches

1. Conceptualization, Policy-Making and Long-Range Planning.

The electonic revolution is hard on us. It its social accompaniment is to move without major disasters, particularly in the moral and political realms, policy planning of the first order of magnitude is required. The knowledge machine and its impact upon education may well be greater than that of the atomic bomb upon warfare. Task-forces of the best minds in the country should open continuing debates upon the issues involved. Long range studies must be mounted to conceptualize and document the problems and issues. The five new research centers just announced by the United States Office of Education are a step in the right direction. 2. Let us hope they will consider at length the privacy and the control issues -- in my mind the most serious of the moral and political questions raised by computer technology. They should also consider the changing role of the school in the total educative process.

These tasks will require Renaissance men -- mature, humane philosophers of a kind not much in demand earlier this century. These wise men must not permit themsleves to be seduced by big money or by the cyberneticians -- a self confident group with a private in-group language. Rather, they need to address themselves to the problem stated in the following paragraph:

> "In the field of computer design the most severe lack of knowledge is not how to design and build bigger and faster machines, but how to make them function, how to integrate them into the human world, and how to make them do what we want them to do. Norbert Wiener's later writing harped upon the dangers we risk by building machines to perform functions that we do not adequately understand. The dangers are real

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1. Arnold Toynbee, The World and the West (London: Oxford University Press, 1963), pp. 74-75.
2. Education USA: Washington Monitor, June 19, 1967

> because our ability to design machines is more fully developed than is our ability to understand the purposes to which they might be put; and we could end by putting electronic machines to uses we would not want to put them if we really understood what the uses were."1.

Further, these task forces and scholars need to think long and hard about the kinds of people and the kinds of society seen as desired and desirable by the end of the century, and about how computer technology can help and how it can hinder such growth and development. Value questions will be paramount.

These discussions and arguments should not be held within ivied walls. They need wide dissemination and involvement by every imaginable variety of citizen, business, government, and professional groups. The continuing dialogue should become part of the atmosphere, just as is continuing discussion about the control and use of the atomic bomb.

Such thrashing out of direction needs to be based upon scientific and technological literacy on the part of participants -- a cross-fertilization of C. P. Snow's two cultures. Such literacy presupposes adult education -- for teachers as well as for interested citizens. Indeed, the impact of technology upon society should be a persistent theme which pervades the entire curriculum at all levels from the kindergarten through graduate school. An immediate step in this direction could well be the sponsoring of a well-planned curriculum project of this nature. Then, at the least, we might start to build a reservoir of informed citizenry, who have more than a nodding acquaintance with the space age, and with the astonishing new developments in biological sciences, as well as with the computer. Designed for both young people and these elders, such a curriculum might help to narrow an otherwise ever widening generation gap.

2. Curriculum Development

Consideration of the need for building substantive curriculum on the effect of technology on society initiates the whole subject of future curricular imperatives. They are multiple. Let us start from the premise that tomorrow's educated citizen will need more liberal education in the Greek sense of the word liberal than ever before. The reasons are obvious. In the first place, the Greek citizen's education will soon be a possibility for every man. Secondly, every man will have the leisure to cultivate grace and beauty, to contemplate the good life, and to wonder about the unknown. Thirdly, tomorrow's citizen will need more direct sensory contact with reality than ever before to counteract the potent artificial environment created by electronic media systems.

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1. Robert McClintock, "Machines and Vitalists: Reflections on the Ideology of Cybernetics," in the American Scholar, Spring, 1966, Vol. 35, Number 2, pp. 254-255.

Increasingly important, therefore, are the arts -- particularly the performing and the applied arts. Physical education should regain the place it had in the Greek curriculum. Outdoor education, camping, and home arts take on new meaning in this context. (Even today we are recognizing that "roughing it" in natural surroundings is now only possible for the privileged few.) Much of tomorrow's curriculum must take place in studios, in laboratories, on trips. Thus children may cultivate their perceptions and delight in the singular -- in the concreteness of everyday contact with the natural world -- in the stuff which makes artists out of people.

Similarly, deep and lasting personal contacts must be an integral part of this new educative process. The warmth of individual for individual and the intimacy of a stable caring community must offset the cool objectivity and impersonality of the machine, as well as provide an important motivational base for further learning. As Gerald Johnson puts it:

> "The knower and the known are not a pair. They are two thirds of a trio. There remains the relation between them, a third factor as important as either of the others. 1.

This relationship must be as much a part of the new curriculum as the direct aesthetic experience itself. Indeed this new curriculum should be concerned equally with process and with product.

This person-to-person contact needs also to be an essential ingredient of the part of curriculum which deals with application and synthesis of knowledge. The community seminar described by Fred Newmann and Donald Oliver 2. suggests this kind of effective background for the probing of intellectual issues. But until such natural and effective forums become part of ordinary practice, the task can be done by the schools, providing they can be backed up with curriculum and instructional materials centering around such vital issues as urban slums, the generation gap, and pollution. The new courses on technology and society mentioned earlier could provide some of the substance for these dialogues.

This call for non-computerized sections of an increasingly humane curriculum does not imply lack of attention to the crying need for more curriculum software for computers. What exists now is pathetically thin. I suspect, however, that we have put the cart before the horse. Surely, except for experimental purposes, we don't want to develop curriculum simply because it lends itself to computer programming. Good curriculum comes first. Then the job is to see what subject matter and approaches can be best handled by the computer. For example, as stated earlier, logical sequences of symbolic learning seem particularly well suited to computer programming. So also are all kinds of informational retrieval

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1. Gerald Johnson, "Some Cold Comfort," in the American Scholar, Spring 1966, Vol. 35, Number 2, p. 194.
2. Fred Newmann and Donald Oliver, op. cit.

systems in all subjects from science to histories of art and music. Games and simulation schemes also seem easily adapted for computer use. But in all curriculum building, the first question to ask is why? Unimportant or mediocre ends will produce unimportant and mediocre means whether the teacher is alive or a mechanical monster.

To summarize, policy makers need to provide for the full-range of a rich and varied curriculum for all sorts and conditions of learners, modes of learning, and subject matters. Whether or not it is to be computerized is a second order of priority. Let us, of course, continue to experiment with computer programs which treat the logical, the symbolic, and the empirical. But let us remember that the better these programs deal adequately with the funded knowledge of mankind, the more important will be the "soft-soft" sides of the present day curriculum, i.e., philosophy, the humanities, and the arts, both fine and practical.

3. Studies of Institutional Change

Dreaming about the educational process of tomorrow and developing new curriculum tailored to the future can be empty exercises if these ideas and materials are not accepted and used. And to date, the schools have been the despair of innovators. During the last decade, a brave new world in the schools was to have been ushered in by the Curriculum Reform Movement, by the advent of new organizational patterns like team teaching and nongraded schools, and by the development and promotion of new instructional media like television, language laboratories, and programmed materials, including computers. Yet despite the amount of publicity given to these innovations and to the examples of a few schools and school districts given national visibility, not much basic change has occurred in the rank and file of classrooms in the nation. Very little has happened of an organic nature or of the proportions required by projections for 1985.

Given this background of experience, what strategies are in order? Is it hopeless to attempt to move the Leviathan that is the public school? Or should the government continue the strategy it has employed within the last few years, namely to by-pass the educational establishment?

Probably both strategies will be needed for some time to come, particularly if the policy makers feel any responsibility toward the current generation of students and teachers now in the schools. In this connection we note that the great mass of public school teachers and administrators and the faculties of teacher-training institutions have not been involved in the excitement of the sixties. Nor will they be in the seventies and eighties if the problems of massive change of a conservative social institution are not faced head on. Attempts to get at this problem have been flying blind much of the time. This blind spot has several causes. One has to do with the lack of real school knowledge and experience on the part of the innovators of the last decade. Another relates to the lack of articulate non-defensive leadership within the schools. A third suggests that the major energies of the Great Society leaders have been more directed toward social problems than toward educational ones. But, for whatever reasons, the fact remains that the task is huge, that a bits-and-pieces approach has been singularly unproductive, and that the full complexities of institutional change have been to date ignored.

At the same time, there are some attacks which hold promise, even though far from fool-proof. One of these relates to applications of systems analysis to the complex problems faced by school systems. Such applications will require conceptualization of the relationships of administrative and managerial decision-making with models of rational planning for curriculum and instruction. Field testing of such models and conceptual schemes is essential to their development and use, and there is a body of theory and experience upon which to build. Furthermore, school systems, whatever their fate, could profit from the self study and long-range planning required by full scale adaptation of systems analysis to their problems. Computers, incidentally, could greatly enhance the proper study of a school system either by itself or by outsiders.

Similarly, a systems approach to the computer as one of many instructional tools is badly needed. Such studies would place the computer in a multimedia context and would examine what learning modes, media, and material seem to work best with what curriculum and with what learners. We suspect, for instance, that there are many less sophisticated devices for enhancing learning (such as the book) which will continue on occasion to be an effective means to an educational end. Systems approach studies could give perspective to the potential of the computer as an instructional aid, refine its contributions, and speed its acceptance by the profession and by the public.

Another complex which requires long-range study is the whole teacher-education-leadership-training continuum. This is an arena which must be entered if change in the school system is a desired aim. Again there is need for conceptualization of the problem and for a systems approach to its administration and management, This approach hopefully would be intimately related both to the multimedia materials approach and to the curriculum and institutional schemes discussed earlier. Only as all the dimensions of the problems are defined can the issue be attached in any rational fashion. Only against such a background can predictions about changes in the role of the teacher make much sense. Thus action research into such issues as the effects of computer-assisted instruction upon teacher percepts of their roles or as the impact of various staffing and organizational patterns somehow must tie into a larger whole. Only under such conditions can we take into account Toynbee's observation that the "isolated part and the mutilated whole behave differently" when they are removed from their natural setting.

Other obvious large long-range studies relate to the school and community structure, to the political decision-making process outside the school system, and to the whole psychology of learning and child-rearing, as well as to the future functions of the family. These studies are undoubtedly under way now in several universities. They need continued governmental or foundation support. Equally important, however, is the building of a cadre of educational engineers or change agents who can translate the results of such studies into ongoing operational school programs.

In addition to all these studies of change within the school system, strategies which circumvent the school establishment need to be explored and their consequences studied. There seems little doubt that some products of this strategy, for example, the Head Start program, promise to have remarkable impacts and staying powers. There is much to be said for the generation of ideas and practice outside the body politic and for the creation of new institutions or agencies designed to assume functions traditionally belonging to the older institutions. These strategies, however, are only successful part of the time. The federal government, we know, has buried countless numbers of task force reports and has often built new agencies on new agencies in the vain hope of breathing life into important governmental functions. Despite this history, it would be interesting to follow experiments with the studio-work-shop-laboratory idea outside of the school, or with local adaptations of the kibbutz, or with computer, or multimedia learning centers, community based and separated from the school. And surely, business enterprises should be encouraged to be partners in the process, providing authorities recognize that they are not infallible either, despite their sophisticated talk and smooth exterior charisma.

Of note is the fact that I have omitted any reference to research and development in computer hardware. This omission is on purpose. I have confidence that the hardware will continue to be developed and be adapted to instructional uses without outside assistance. Rather, my plea is for software, software, and more software. Perhaps this is an incorrect use of this term, but my definition relates to the messages the computers will carry, such as sequential skill development in mathematics or retrieval systems for topics in the social sciences. My definition of software also includes the promotion of programs, like the development of small, family-like, outdoor camps, designed to offset the environment created by the computer and to balance the "new" curriculum. In addition, my "soft-ware" encompasses public examination of the emerging new roles for schools in our society, and searching appraisals of the political and moral issues relating to control of the knowledge machine.

Conclusion

All the studies and researches and programs related to the school and the computer are important. Were I a maker of policy, however, I would give first priority to the establishment and maintenance of dialogues about education in every form and market place in the land. The major topics would be:

1. What should be the role of the school in tomorrow's society?

2. What authorities are to have the responsibility for control and regulation of education, in or out of school?

3. Who will control the knowledge machine?

Again, were I a policy maker, I would approach the task with fear and trembling. Tampering with the functions of a major social institution is a risky business. Yet the electronic revolution leaves us very little choice. Either we consciously take on the job or the knowledge machine will do it for us. Kierkegaard spoke truly when he said, "Dread is the possibility of freedom."

Dr. McLoone's discussion of the economics of the new education contains a host of ideas and dreams of the system that technology may produce. In doing so, it highlights some of the conflicts and ambiguities of our emerging educational system. It also points to some of the technological and methodological gaps that may affect the future. His system analytic orientation and his logical derivation of its consequences for political, economic, and social organization is challenging. One may disagree with his predictions for the future, or with his assessment of their effects, but one will not read them unmoved. The direct approach to critical issues of this thoughtful and thought-provoking educator-economist will elicit both fear and hope.

THE INFLUENCE ON EDUCATION OF THE SEVENTIES

Technology of Computers and Systems Analysis

Eugene P. McLoone

A "far-out" projection of the educational system is presented so that the influences of science and technology on education over the next ten to fifteen years may be examined. Identification of the various cost comparisons highlights the steps in the development of the system. Finally, the major decision points are reviewed.

A Look at Schools of the Late Seventies

Now, in the late 1970s, the use of systems analysis in education has resulted in the specification of the primary objectives, the secondary objectives, and the important by-products of schools. Capital-intensive processes have been developed to accomplish most of these objectives. However, the baby-sitting function of the schools which allows women to work has greatly limited the implementation of the capital-intensive process. As a result of this limitation, a new institution, called "community service center," has been developed to perform the educational and baby-sitting functions. The center is a combination playground, day care center, social learnings center, and location for machines that perform the normal instruction. All children spend some time at the centers, participating in socialization activities, important group learning activities, and consultations with teachers. Although learning by machines was planned to enable most children to pursue their education at home, most of them still come to the community service center to use the free-standing and on-line interfaced computer programs. The equipment gives each learner access to all subjects and all media. Films, slides, photostatic copies of books, and so forth, appropriate to the subject matter and students, are available at the learning station of the center. Most of the learning is geared to the successful completion of a task and is presented sequentially, but some tasks are designed to challenge the student to transfer his learning to new situations, and to extend his performance beyond step-by-step progress.

All educational equipment provides the student with an evaluation of each of his learning experiences. This information is supplied directly to the learner and is stored in a cumulative file, which includes data on specific achievement, cognitive style, health, and individual attitudes. Feedback of this information into the total system provides a self-adapting process that leads to continuous improvement of the total system -- in much the same way that a computer programmed to play chess improves its own skill.

Research is carried on with this stored data, and questions are answered. The learner decides what to study and for how long, thus enabling the system to provide data for continuing research on the time span of attention and the level of difficulty of material. Periodically, the teacher checks on the learner by requesting information from the computer-stored cumulative file. The computer compares the learner with similar students and suggests next steps. Each teacher accepts or rejects the suggestions, or carries on a dialogue with the computer to learn differences between his and the computer's perceptions of facts and assumptions. The teacher's judgments are stored and fed into the system. Similarly, administrators evaluate teachers by requesting data from the computer on teacher decisions. Administrators' evaluations are stored and used by the system to indicate the need for teacher-administrator conferences. These person-to-person meetings help the individual accept the stored knowledge and experience of the computer as they apply to the individual and his decisions.

Samples of learner responses are made and supplied to educational "software" manufacturers so that they may revise and improve their products. Similar samples provide information for national assessment of learning and instruction, and supply data relevant to the education of teachers and administrators. The sampling schemes for the education of teachers and administrators provide data for simulation of educational decisions, and for the comparison of the individual's judgment with that of the computer system. Other sampling procedures permit studies over time, studies on learning theory, and studies on evaluation of equipment and software.

Education has changed, but it is still the subject of much controversy. Debate rages as to who should have access to what information, and how privacy should be assured. Debate also rages as to how much of the total system should be interconnected, and as to the proprietary rights of individuals and groups to educational materials and equipment. Should not all children have access to the best programs? Should the tie-in be via telephone lines or by the reproduction of software? How long should public investment in the learner, at no direct individual cost to him, be made: Until he achieves a certain level of performance? Until he uses a certain amount of material and financial resources? Until he is a certain age? The choice has been to provide resources to a learner rather than to a teacher in a classroom. Yet members of the educational profession continue to dispute which materials should be directly available to the learner, which should be available to a professional for transmission to the learner, and which should be available only through a public institution such as the community service center.

The computer automatically awards diplomas and degrees, complete with delivery of a society-oriented commencement address, personalized for the individual graduate, when the learner has passed significant check points. Engraved, personalized diplomas come to the student at the learning station just as does any printed material. Individuals prefer some tangible evidence of performance, such as the diploma, which they can show others. Since the computer can keep track of more skills and performance than was previously feasible, a wider range of evaluations are available. Employers are interested in the detailed analysis and may ask the computer to compare the skills required of an employee with the cumulative record of the prospective employee. Deficiencies are noted, and some persons are hired provisionally until they have taken the required computer programs. Employers who complain that certain skills are not taught well enough by the public educational process require that new employees complete supplementary programs on the employers' computers.

This view of the future could be continued to show that such a scientific-technological system of education mainly provided check points for personal decisions and person-to-person interactions. Much communication took place via computers, and many computers made "better" decisions than did their programmers. The use of computers to make decisions allowed less experienced persons, such as learners, to make decisions as "good" as those of more experienced persons, such as teachers. Computers easily stored, retrieved, and analyzed data. Through a large memory system, computers built experience and knowledge beyond the capacities of any single individual. Through a feedback of information to the system, data-based decisions were self-adjusting, and processes were established that extend decisions beyond those based upon the best human judgments. The systems approach made it possible for a computer to perform these complex tasks by means of a series of minute steps, which are trivial to it but enormous in number for a man. Breaking down and rearranging steps often resulted in new sequences and in the application of new thought patterns to a task. Use of the systems approach in education made possible this "school" of the late seventies.

How the "School" of the Seventies Developed

Systems analysis came to education simultaneously from several directions during the early sixties. Electronic data processing (EDP) was adopted by school administrators for financial and pupil accounting.

Planning-programming-budgeting (PPB) systems were adopted by the federal, state, and local governments. Packaged educational systems (PES) were developed by the education industry to accomplish both the clearly stated objectives of industry and government in the training of employees, and the similarly clearly stated objectives for those groups of the population for which traditional schooling had failed. Educational researchers in the field of computer assisted instruction (CAI) and in other fields where computers were used, applied systems analysis to their work in the schools. At first, each group operated independently. Gradually, some systems became subsystems of a larger system, as systems analysis was applied to more and more of the educational objectives and to the procedures for reaching those objectives. Rapid, widespread use of latest developments resulted, as the continuous process of systems analysis, with its feedback of information, became more embodied in capital goods.

Installing an EDP system required systems analysis of the management tasks of the schools. People with systems analysis skills were attracted to almost all state departments of education, and most of the larger school systems. Many of the smaller school systems cooperated in EDP programs. At first, programs were adopted from business to perform payroll, supply inventory, and similar operations. Later, EDP systems were expanded so that the cost of teaching certain subjects, the distribution of funds among students pursuing different courses could be determined. School administrators discovered that it was possible to compare expenditures with accomplishments, and not just "things bought" from one year to another. Although no study as yet clearly separates inputs and outputs, the future promise is clear from studies such as (authors) Jesse Burkhead, Thomas G. Fox, and John W. Holland, "Input and Output in Large City High Schools." Syracuse Univ. Press.

The PPB system provided the same type of information. Federal officials, state legislators, and non-educational local government officials wanted such information upon which to base their decisions. The systems approach thus was applied to budget decisions of schools and to the use of resources within schools. Objectives for part of the instructional program were specified by CAI researchers. Given these objectives it was possible to compare the cost of different methods of instruction in achieving the specific objectives. A computer program was designed to make similar budget decisions on its own, using the experience of several experts to establish limits on expenditures for given objectives. The program was built on experience, and gradually the decision maker had to determine only when to trust the computer decision. A dialogue with the computer enabled him to make this determination or to modify the computer's decision. The result of the dialogue also became part of the computer program. Eventually, other schools used this procedure, and the number of routine and normal tasks of management became increasingly fewer. This permitted the Administrator to move to higher levels of operation and address himself to more complex problems that are less amenable to computer manipulation.

The systems approach, however, did not stop at management of schools. The "new breed" of personnel developed for management tasks in the business offices of schools now extended their analysis more and more to the instructional program. A few packaged educational (FES) systems had been developed, which embodied both the subject and the teaching method in capital equipment for clear-cut objectives. Some FES required a particular computer, but most of them were adaptable to various pieces of hardware. Available time on the computers used for EDP and PPB systems provided a ready means of checking the advantages of some PES for new objectives.

Since the development of FES had been influenced by business, by research on CAI, and by engineering, the success of the system for limited tasks raised the question in industry as to how the tasks and thus the market could be expanded. Some new firms entered the field; In keeping with the tendency of systems to complete themselves, some producers of elements of FES sought to expand their share of the market and to expand their capability for producing entire FES (hardware manufacturers devised software and software manufacturers, hardware). School administrators and teachers with EDP and PPB experience were able to define new tasks for which they could use equipment, and were also able to suggest expanded use of present equipment. Research in CAI indicated other aspects of development and engineering problems. Engineering skills were provided to design interface equipment for small children and for tasks unique to schools. Many of the engineering contributions grew out of work related to problems of computers and computer systems, without special regard for schools. The possibility of profit from the school market, however, made investment in engineering research a better risk than previously for many uniquely educational tasks.

The CAI projects not only provided initial experience with FES in schools but also indicated the larger possibilities in the breaking down of the educational process into small tasks with clear-cut objectives. Satellite research projects around CAI projects relative to learning and teaching solely by machines provided many answers to basic questions. These findings were incorporated in the design of later FES. Basic scientific research on interactions among children, status structure, effects on learners, and so forth showed that little of the learning process was lost if equipment and programs were properly devised. As more and more of these findings became embroiled in capital equipment, the learning environment became increasingly a controlled environment, and additional progress was made in identifying next steps. Capital-intensive education was of a different order of magnitude than was traditional education, in that it embodied the best of the new ideas and permitted rapid widespread use of them.

Some state legislatures and some large city school systems purchased FES for most of the educational tasks. They even provided development funds for elements that were not available, since by extending the time horizon of decisions, PPB systems had shown them that spending for development was preferable to sharply accelerated salary payments over a long time period. The difficulty of recruiting capable staff underscores the move in this direction. Systems analysis in local schools had identified elements of the educational process where development should take place. In some instances, PPB analysis had shown that added objectives attained by use of the PES made large additional expenditures desirable. And citizens were willing to vote taxes to achieve clearly defined objectives.

The success of PES in one school district resulted in other school districts wanting access to PES. Competing networks developed. However, gradually the exchange of information on PFB evaluation indicated that certain PES were better than others. New PES were modeled more and more after those that were most effective and least costly. Gradually, there came to be only one PES for each objective. This uniformity was masked by the differential packaging of the same PES by competing producers.

Not all development was smooth progress toward the present "school". Early, a guidance system was developed in which the computer administered standard tests on vocational prefererance and interest. The computer was also given the grades of the pupils and Scholastic Achievement Test Scores. Admissions offices of all colleges supplied their criteria for the selection of students, including random selection of a portion of the entering class that otherwide did not qualify; the business offices supplied their tuition and fee requirements; and the scholarship offices supplied their criteria for awarding loans and scholarships. When the pupil finished his standard tests, the computer indicated the "best" field of study and the "best" school to which he should apply. Multiple applications to colleges were avoided and anxieties over being accepted or not were eliminated. This network of information in a usable form relieved many persons of routine tasks. However, not all students were happy; some sought alternatives for fields of study or colleges. Some students tried to find out from friends how to answer the questions so that they might go to the college of their choice or pursue their chosen field of study. Parents complained that they wanted their children to study another field or attend another college. They felt that it was unfair for the computer to supplant them, especially when its recommendations ran contrary to their wishes. College alumni complained that their influence had declined. Guidance counselors in some schools complained that they had nothing to do while a child was on the machine. The counselors who worked in developing the program demanded royalties whenever it was used. Eventually, part of the funds paid for participation in the system were set aside for retraining of counselors.

The experience in overcoming early difficulties resulted in ground rules for further development. For example, experience with the guidance computer also created a desire for more leaps ahead; and more networks of information to relieve persons of routine tasks were requested. A student-computer dialogue was instituted to convince the student of the objectivity of the computer choice. College grades and eventual job success were fed back to improve standardized tests and the computer selection. College admission policy changed from requiring Carnegie Units and Scholastic Achievement Test Scores to requiring accomplishment of computer programmed tasks, and the first of many breaks in the old lock-step system occurred. Admission was based on measured performance and not time spent in school.

What Cost Comparisons Did the Decision Makers Use?

Cost analysis began with the concept of "pure" economic efficiency, in which resources used were compared with objectives obtained. As systems analysis grew and as ideas became more and more embodied in capital equipment, there was a need to change objectives as well as resources used. Neither educators nor system analysts desired to change the objectives of the schools. Everyone wanted the schools to continue to perform all its objectives. Nonetheless, capital equipment and systems analysis modified the objectives. The primary objective of the schools was education, that is treatment of the child so that he is cured of the disease of ignorance. Secondary objectives and by-products of the schools such as custody, that is providing a safe place for the child in society which has no other place for him, were ignored in designing capital equipment and in doing systems analysis.

Systems analysis tended to use the measurable objectives of the schools. It recognized those not amenable to measurement and treated them as a residual component in the analysis. Objectives embodied in capital equipment were more easily measured than others. Thus, distinctions were made among the objectives of the schools; some objectives were measurable although not embodied in capital; and some objectives like those of custody were given no importance in the analysis. Cost comparisons tended to ignore the residual component not readily subject to measurement and then, cost comparisons were made on a "mixed efficiency" basis in which objectives were redefined -- the analysis was limited to the measurable objectives.

In both systems analysis and in the design of PES, one may well assume that the process of acquiring an education is a normal process. As Dean James says, "Given the assumption (that acquiring an education is a normal process), we might find when the normal child responds to the stimulation of the environment presented to him, our concern need be only with seeing that the environment is properly stimulating, with devising ways to minimize the need for personal services, and with monitoring his responses to see that they continue to be normal." Expensive personal services can then be organized to maximise their availability to the abnormal child, the one not responding normally to the stimulation of the school environment. "... the normally curious child may have diminished needs for the continuous surveillance by a teacher, may in fact progress much faster if left to work quite independently through planned programs, with only periodic check-ups and occasional corrective measures prescribed by the master teacher. This does not mean that we will need fewer teachers -- the probability is that we will need more -- but means rather that the teacher will use her time more effectively to facilitate the learning process."

Thus, there may be a tendency among systems analysts and developers of PES to forget the *custodial* functions of schools.

These ideas of the two broad functions of schools - custody and treatment - and treating of education as a normal process of the normal child, are ones often expressed by Dean H. Thomas James, School of Education, Stanford University. He has developed them at length, in unpublished speeches.

The ultimate was reached in PPB systems when the analyst based judgements on "total efficiency", that is, he altered both ends and means (resources and objectives) simultaneously, and made them dependant on changes in the political relationships".* Then cost comparisons were made on a "total efficiency" basis. Education was evaluated as were space programs. Expenditures for the space program were not only justified in light of the primary objectives of placing a man on the moon, but also on secondary objectives such as the program effects on (1) solution of air and water pollution problems; (2) medical science; (3) creation of new industries and new products; and (4) even motivating student to study. The system boundaries, which were very clear in cost-effectiveness analysis, become less and less clear as decisions moved from "pure" economic efficiency to "mixed" and "total" efficiency. Wildavsky pointed out these changes of direction. Iannconne≠ showed how state policies on education had moved from professional to partisan decisions, that is from a judgment of "pure" economic efficiency to ones of "total" efficiency, after remaining some time in the realm of "mixed" efficiency. Nonetheless, the voters and their representatives raised questions which dealt with education of individuals, and not necessarily with the formal schooling institutions which provided only part of the education. Almost all economists make a distinction between "education" and "schooling". The latter deals exclusively with the formal institutions and its product. The former deals with all factors contributing to the education of an individual. See for instance, Schultz, Theodore S. *Economic Value of Education*. There was a desire to move in the direction of "total" efficiency, and in raising these questions, few realized that the choice was between the schooling institutions and the new values of education, and that the choice was toward education without caring for the schooling institutions. The system boundaries increased.

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*Wildavsky, Aaron - "The Political Economy of Efficiency: Cost Benefit Analysis, Systems Analysis, and Program Budgeting". *Public Administration Review*, Dec. 1966, p. 292.

≠Iannaconne, Laurence, "State Government and Education", *Proceedings of Conference on the Emerging Role of State Departments of Education with Implications for Vocational Education*. Ohio State University. To be published Summer, 1967.

The individual learner had always been the object of the educational system. Nevertheless, resources were almost always provided for the learner in a classroom with a teacher. Individualization of instruction implied providing resources to the learner and not to a teacher in a classroom. Extra resources for special groups, such as Operation Head Start and the Job Corps, also implied the dedication of the learner toward the advancement of a given task than toward an element of the formal school structure. Cost comparisons, such as those of thirty-five cents per student hour and so many man-hours for preparation of an hour of student learning, implied the same attitude. The systems analyst did not intend to change the educational system; he only sought to evaluate its effectiveness on its own terms. Yet he unquestionably followed the basic assumption of resources being provided to the learner.

Because of different rates of learning, individualized computer instruction proved a better use of resources, including student time, that did classroom instruction. Since student time was costless to schools educators regarded it as a free good. It was, and remains, the resource used most. Consideration of the broader questions of length of time in school, period of public investment, ease of retraining, and ease of branching led the analyst more and more from the old formal schooling system toward individualized instruction. The analyst's comparisons of resources used relative to objectives attained, changed school organization and time scheduling. The objectives of the schools were broken down and rearranged in such a manner that the schools no longer resembled the school as we know it. Which of the tasks defined by the analyst the school could best perform remained to be determined.

Comparable analyses were taking place within corporations, in designing products for schools, Citizens and decision makers at federal, state, and local levels were similarly engaged. These evaluations compared existing programs with possible alternatives. The resources required to attain an objective established the limits for trying to develop a new PES or for establishing a system analysis capability. Setup costs made the progress slow but the results caused the system to spread rapidly.

Most of the decisions about PES and other new developments were made by comparing one or a few objectives of the schools with present cost and proposed cost. PES were adopted when they performed the task as well as or better than did existing methods at the same or lower cost. When PES attained objectives not attained before, they were often adopted regardless of higher cost. Citizens, at times, demanded PES simply because they themselves could then evaluate the resources used for an objective. Tasks of schools passed to others as PES provided means of doing these tasks directly without the school as an intermediary. The widened range of choices changed cost parameters and allowed more decisions to be based on judgments of mixed efficiency. The longer time span for evaluating expenditures within PPB systems also changed comparisons of capital and current expenditures. PPB systems, by evaluating the resources used for objectives, gradually widened the boundaries until more and more decisions were made on the consideration of "total" efficiency.

Summary

So much for the Shape of Things to Come, we must now consider the next steps from today.

If it is agreed that the educational system as **hypothesized above** is desirable and that the direction hypothesized is the path along which we currently are going, then we are indeed committed to the decision for a "total system". However, we are not without freedom, many opportunities exist for alternate paths. If there is agreement on the general hypothesized lines without regard to many specifics, then the three major decision pivot points seem clear: (1) train analytical personnel so that local schools can perform systems analysis and fund setup costs; (2) support satellite research around CAI to give basic science answers to many questions about total learning and teaching; and (3) develop and initiate one or more "jumps" beyond gradual normal development. (Kuhn, Thomas S. Structure of the Scientific Revolution).

The tools of systems analysis are useful to education in making the educational process more rational, more systematic, and more directed toward objectives that it is at present. Very soon, systems analysis will require a "new breed" of professionals who possess the knowledge both of education and of systems analysis. Meanwhile, personnel need to be attracted to education to set up systems and to provide in-service training. Progress will be made by bringing together the competencies of people from systems analysis and from education. They will need to work as a team. Hiring of these personnel, who are most likely to be hired for EDP or PPB, will often mean paying salaries above those provided to school staffs today, because their skills are in scarce supply. These personnel costs and the costs of setting up the system in a school will be a bottleneck unless local school districts receive special aid. Eventually, the cost of operation will be borne by ordinary tax monies.

On-going CAI operations in schools under research give an indication of the present limits of equipment and the possibility of embodying ideas in capital goods. Before there is more widespread use of CAI in schools, basic questions relative to all the learning that takes place and the changes that occur in learners need to be answered. Basic scientific research by many people in many fields is required to answer these questions. The answers are needed both to satisfy the public and to design better capital goods than are now possible. At least one CAI project should be made an adjunct to a data processing operation so that experience about adoption of CAI through this route is obtained. Using available time on data processing computers of schools may be the easiest path to the widespread adoption of CAI.

The development of a "jump" by means of a guidance system or a budget decision system, for example, seems desirable. In such a development, one could show the possibility of a multidimensional task, requiring large amounts of data and testing of several hypotheses, being performed as no one person could perform it. It should show how experience and knowledge are maintained and built upon in the computer. It should also show how capital goods could replace labor, so that adoption of the system would reduce costs of present school operations. It is likely, however, that new tasks will be set for the schools. These tasks will require increasingly sophisticated activity by the schoolroom.

The choice of these decision points rests on the assumption that parallel progress will continue in engineering and development of PES by commercial corporations. Engineering will move in those areas where products are multipurpose, and special educational uses can be readily adapted. Some engineering will be performed for educational purposes because of PES in industry and government, and because government will purchase some PES for educational objectives. Some PES for schools will develop as systems analysis breaks down tasks of schools into smaller and smaller steps. Some will be adapted by industry from those PES available for other purposes.

In turn, the above statements rest on the assumption that the basic problem of developing PES is one of doing systems analysis on the educational process. Segments of the educational process for specific objectives can be embodied in capital goods successfully only after prior systems analysis. The systems approach by itself, even without capital goods, will do much to improve the educational process. However, if software is developed and embodied in capital goods before systems analysis is performed, present inadequate methods and traditional subject matter will be embodied in capital goods and the capital-intensive system will continue many of the defects of the present system. Specifying the educational objectives and details of the educational process can be done well only in an on-going operation, and even then the details can be rearranged and sequenced toward a definite objective only when the details and objectives are clearly defined. The defining of objectives requires a continuous process for closer and closer approximation of precise requirements. The significant change in education by PES is not a more capital intensive system than that of today but a more systematic process than today. Capital-intensive may mean only that effects are long lasting, and that the time span of each decision must be extended.

Addendum

The following are definitions of "systems analysis". The first is from Kershaw, Joseph A., and McKean, Roland N., Systems Analysis and Education, Rand Corporation, Santa Monica, Calif. 1959, 64 p., the second from the New York Times for June 16, 1967.

A. Explanation of Systems Analysis:

"Our concern has been with the possible applicability of what is often called 'systems analysis' to some of the more important problems of elementary and secondary education. Essentially, systems analysis is the comparison of alternative means of carrying out some function, when those means are rather complicated and comprise a number of interrelated elements. Such analysis could often be called 'economic analysis', since the aim is to find the best use of one's resources, but the word, 'systems' is useful in calling attention to the complex nature of the alternative being compared.

"The purpose of comparing one system with another is to show which is better. Or, more frequently, since quantitative analysis can rarely embrace all considerations, the purpose is to compare systems in a way that is relevant to a choice between them and helps one to decide which is better. Only one of the systems compared will ordinarily be an existing one, for the object is to 'try out' innovations and new proposals in the comparisons - to compare a system as it exists with what it might be after one or more proposed changes are introduced. Indeed one of the main products of making such comparisons is the devising of new and better variants -- the design of new systems.

"By 'system' we mean a set of interrelated factors that are used together to produce an outfit ... systems also have costs associated with them, costs that may be expressed in dollars, or in labor of certain specified skills, or in lives lost, or in smog produced, and so on .... Finally, in all of these systems there are various ways of combining the elements or inputs in order to produce outputs. This is what makes the system interesting from an analytical point of view; it is possible to vary the inputs and see what the effect is on output. We can educate children, for example, by having one teacher for each child, or we can do it by using one teacher for fifty children. Presumably, these two different combinations will yield different outputs in term of the amount of education obtained by the children in each system....

"In a successful systems analysis, the analyst can vary the inputs, note the effect on both cost and output, and then decide that one system is better than another. He can tell you that if you have a certain sum of money, and if you agree with him on what is to be produced, your money is best spent on a combination of inputs he can specify because this combination will maximize output. Or, what is logically equivalent, if you tell him what output you want, he can tell you how to get it at minimum cost." (p. 1-3, Kershaw and McKean).

B. Quote from New York Times

"Systems analysis, in the simplest terms is a method of analyzing by list the desired objectives and available resources, then determining the alternative methods of using these resources to gain the objectives.

"The systems approach also involves looking at a problem as a whole and dealing with the interplay between parts of the problem as well as with the parts themselves.

"Rand thinkers call this approach 'applied common sense' but sometimes it leads to a basic instructing of key problems." June 16, 1967.

REVIEW OF THE SEMINAR

J.B. Margolin and M.R.Misch

The sections that follow were prepared by the professional staff of the Educational Policy Project. They are intended both to supplement and to bind together under different headings the contributions of the members of the panel. They reflect not only the formal papers, but some of the material recorded during the seminar.

As we consider the courtship of education and technology, we must note the differences in personalities between the two and determine their capacity for adjusting to each other. Current technology is heavily systems oriented, and primarily profit motivated. (We should qualify this by noting that the enthusiasm of so many in industry and the R & D organizations lend a motivation and a purpose that would seem to exceed that derived from dollar gain.)

Education is not like other industry. There is frequently an insistence on orthodoxy, and a slowness to change. This is not limited to one part of education, it includes research design, curriculum development, theory, and pedagogic method. This is not without cause. Education has not been a favored industry despite the weight of responsibility for the future that rests on its shoulders.

That there is hope for the union may be seen in the papers that follow, those from Academia, education, and from industry. It can also be seen in the coming together that may be observed in the increased systemization of education, and in the questions of a distinguished industrialist at a meeting sponsored by the National Committee for Support of the Public Schools:

> "Can education give our new generations genuine self-confidence, genuine courage, and, at the same time, teach them that they must themselves discover the new truths?
>
> Can education, through a better concept of teaching durable disciplines and transferable skills, help create people who are equipped to shift comfortably from one challenge to another - who can rationally manage one set of unpredictables after another?
>
> Can education help suppress the development of defense mechanisms which prevent most of us from seeing the world as it really exists?
>
> Can the educational environment in fact help provide the emotional security which enables one to recognize that life is indeed filled with risks and ambiguities, and that the great human achievement is to deal with them creatively and joyfully rather than be blind to change, or even worse, fearful of change?
>
> Can education broaden its mission to include the

> development of the total human being, to help him achieve his total human potential, the full humanhood 1984 will require?
>
> The Class of 1984 will be stepping into an unbelievably exciting, but also a new kind of world. This new world will demand a new kind of person...a person with genuine flexibility and freedom, a person who thrives on sensing and solving problems as complex and subtle and new as the technological environment of tomorrow. In this new world, rigidity may actually be a greater barrier to progress than ignorance." (190)

In this report, no extensive attention has been directed to hardware development or to such telecommunication areas as the use of satellites, microwaves, and lasers. It may suffice to say that approximately 40,000 business machines (computers and telecopiers) talk to each other each day in the United States, and yet only 1% of all computers in service are connected through telecommunication. Ten years from now, at least 50% of the then current number of computers will be working together on a real time basis. This rate of conversation today exceeds one and one half million words a minute. We have attempted to stress the policy issues affecting the financing and use of the new technology, rather than construct fact or fiction about the shape of its development.

In the pages that follow, we will deal with 1) the kind of future we expect; 2) criteria for evaluating the alternatives and their feasibility; 3) the methods for achieving desired goals. It is not an uncritical testimonial, nor is it a scathing attack. Instead it attempts to be a constructive assessment of some of the positive and negative potential of a new system that will inevitably have effect on education.

The approaches to the future employed by the members of the panel may be divided into two categories. Some would and did make the great leap into the future, projecting its nature and then drawing trends and policy issues from the objectives that society and science would seem to have set for themselves. Others on the panel rebelled at the prospect of brainstorming and "blue-skying" and operated on the principle that the future begins tomorrow. These preferred to draw a gradual set of trends into the future, observing and noting decision points and policy issues as they proceeded.

It is the intention of the author-editors to employ both techniques in a complementary fashion. This is the way society operates. It has goals, objectives, and ideals and it sets about the deliberate and sober process of future-making, pushed by today and pulled by tomorrow.

The Goals of Education

The objectives of the school in the society of tomorrow have been made explicit in only a few of the articles, but the question underlies the entire project and is fundamental to how CAI can contribute to the world of tomorrow.

The goals of education are in some ways rather too difficult or too easy to define. It is all too simple to say the goal is to educate, or to train to certain skills. Education involves preparation of learners for an exceedingly complex existence, and one that is sure to change before the process in completed.

Thus far education has operated for the "benefit of the individual and the society." However, it has sought these goals in a less than efficient manner. If we approached concensus in the Seminar, it was in favor of systems analysis in education. There was some urgency expressed that the determination of goals and social objectives must be followed by some objective manifestations of the achievement of these goals and how we might demonstrate that they are being approached.

There was also agreement that education should and would seek to extend its social utility. Bringing together the objectives of society and the individual is not an effort to serve more than one master, it is an effort to serve the added function of reconciling man and his society.

Thus the objectives of education on the broad scale are exemplified by:

1) dealing with the needs of marginal economic groups
2) extending its service to younger and older segments of the population
3) dealing with the rapid pace of job obsolescence.
4) dealing with other changes in the economy such as increased leisure.

Each of these examples of the goals of education would seem to bring the school and the society closer together. It is possible to project the need for a school that is sufficiently integrated into the community and the society that it is able to prepare young students for life in the community, and maintain its relationship with them so that they remain technically, personally, and socially attuned to the needs of society and their own needs. Dr. Schure's Comprehensive School District offers an opening wedge in the development of such an agency. In it the learner would be part of the community and in school at the same time. The decision to follow this route would bring the promise of greater congruence in the school-community relationship and in the life of the individual seeking to relate his person and his skills to the opportunities and responsibilities provided by society.

Schure suggests that the comupter must go beyond mere facilitation of learning, that the computer must force the student and the decision maker to become more aware of what the learning process in the learning situation actually entails, and the ways in which that knowledge can be utilized to permit the student to cope effectively with the problem and with the environment that surrounds the learning situation.

On the only slightly more down-to-earth problem of learning versus teaching, B. F. Skinner becomes a bone of contention among the panelists. His statement that "If you know what you're trying to do you are training; if you don't you're educating," would be met by a mixed response from this panel. There was, however, the impression that education was capable of more systematically derived definitions of its objectives. Kropp sharpens the issue be asking whether the objective is educating the learner or teaching the subject.

There was, however, greater agreement with Skinner in his contention that what interests the professional may not interest the student seeking to follow that calling. (Simulation studies could shed more light on this process). This paradox does define one need of education, that of learning the relationship between the kinds of motivation operating in the student and the kind of curriculum that will result in his optimal preparation for the changed needs and attitudes of the functioning professional (or artisan) of 6 to 16 years later. Such an effort would, however, seem to presuppose the learning of basic skills and how to take advantage of a continuing educational system rather than the reinforcement of information or skill in a training mode.

Such a flexible education would seem to be the objective of the organic curriculum as described by Bushnell and Morgan. As a result of this integration of academic education, occupational training, and personal development, the student upon leaving the school would be equipped with entry level occupational skills as well as the qualifications necessary for continuing education. In this program we see the emergence of well defined educational goals at both the general and the specific levels.

Is Individualization a Goal?

Meierhenry comes directly to a critical issue by asking whether individualization is really the goal we seek? Is it one means of providing improved instruction or is it a goal in its own right? It is his view that the computer itself will provide some answers as to which kinds of materials are best handled on an individual basis and which on a group or other basis. Several years ago Cronbach warned that the Zeitgeist leaned to individualization, but such a direction must be demonstrated as superior to teaching aimed at the mean of the group. Meierhenry and Carpenter introduce the more complex question of how we can achieve our goals by integration of individualized with group techniques while yet preserving the advantages of the new technology.

Meierhenry sets forth another possible criterion for the goals of education. He submits that the learner may know what he needs to learn and how he can best approach it. This is not offered as a radical philosophy, but as another approach to a true individualization based on the interest and motivation of the learner. It would integrate the learner's wishes into the system of decisions determining how he learns.

From a larger view it is likely that the forces determining the goals of education will derive partly from manpower needs and partly from political and social needs. How these relate to the goals of the individual will be determined by then current value systems. We can set as our goal an educational system perhaps on the model of Schure's Comprehensive School District, that has as its objective the consonance of individual and group goals.

Changes in the Educational Process via CAI

The use of the computer may have profound effects on the process of learning. Most certainly, if it is to be used as more than a simulated teacher, it will bring new input and new configurations to the learning process. Moreover, as we have observed several times, it has the capacity for improved recording of the behavior of the participants so that we can learn about the learning process and the modifications wrought in it.

We have used educational process and learning process interchangeably. Some clarification is in order. The fashion used to be to refer to programmed teaching. It then shifted to programmed learning, although the process involved frequently continued to be programmed teaching.

Dr. Wilson urges that we place more emphasis on the learner process. The teaching remains programmed in that there is a burden on the teacher-programmer to set the stage. But the other need is for a stage that will give the learner the chance to organize ideas, facts and things to achieve a discovery process. Without becoming excessively involved in the struggles of learning theory and cognition, the work of Piaget, Bruner and the Gestalt school make a good case for continued research in the cognitive and motivational merits of such an approach. Dr. Duhl and other researchers of the panel support this view, and ask for R & D leading to alternate educational models. Another observation that does derive from the discussion would support the systematic quality of education. It must be regarded as a total system including learner, teacher, material relationships, setting, etc. Without such a systems approach to research and application, the potential for error accelerates rapidly.

The use of the computer for the developing of solutions to problems in the sciences, mathematics, etc., provides an interesting and potentially useful shift in the perspective of the student. The learner is required, by the discipline of the programming process, to understand or at least to know the sequence of steps necessary to solve a problem. Having programmed the computer, the student can require the computer to perform the task, using the steps that he has provided. His point of view however is somewhat different from that of a student wielding a pen who automatically defends his steps. He can shift to judge or teacher and observe the solution critically. By assuming the stance of at least two parts of the system he can determine its efficacy and perhaps make improvements. Furthermore the successful solution is imprinted or reinforced even more effectively.

Dr. Meierhenry reminds us of the significance of the medium or the sensory modality to the psychological process. He suggests that visual communication can linger before the eye longer. He urges systematic research into the types of communication that take place via the different modalities so that we may understand the process that we are influencing. Dr. Meierhenry believes as do most other members of the panel that the multi-sensory terminal in combination with programs designed to make appropriate use of combinations of sensory modalities offers the greatest promise. The use of the "dry lab" in chemistry, physics, perhaps even in economics and behavioral science offers a real challenge in such use of combinations of modalities. We are also challenged to understand the characteristic of disciplined fields i.e. chemistry, math, etc. Does each have a basic structure? Are there unique ways in which structure and content can be communicated to the learner? We must also consider the blending of courses and content that constitutes one of the great promises of individual programmed instruction. If we decide to serve the unique interest of the individual scholar, we must learn something of the conflicting or mutually enhancing characteristics of the new configurations. For example, would a study of the mathematics of history provide conceptual and cognitive problems or can it be made to achieve greater unity? The design of teaching materials remains perhaps the most basic element in the system that has not received proper attention, attention based upon research into the learning process and the characteristics of students as well as the behavioral objectives of each course. The potential of the computer to learn alternative answers and to modify the program or at least suggest modification to the authors has been employed by only a few. The design of teaching sequences, or the pattern or gestalt of such sequences, is also a critical issue in software development. The advanced engineering development that we have seen suggests that the scientist and educator will have the equipment with which to engage in the necessary research.

We have also observed that the privacy of the terminal together with the "groupness" of the interactive classroom and the group game or simulation offer a wider range of relationships or settings to both teacher and learner. It is our expectation that with the advance of technology the learner will be offered the optimal circumstances or combination of circumstances for learning. Some of these may exceed today's imagination. Combinations of satellite and simulation crowd the imagination even now. As a tempting, even likely, example of conservative forecasting, can we look forward to computer simulation and games and translating equipment that will permit French and American students to share a class in modern history, or Russian and American students to share a class in contemporary economics?

Some "far out" possibilities derive from the new knowledge of and possible changes in the educational process and individual learning. It is possible, particularly in higher education where the custodial function is not salient, for basic changes in scheduling procedures to occur. If learning does take place in cycles and if there are periods where non-engagement in study is indicated, is it possible that the computer can supply enough information to signal the advent of such a vacation? In terms of the learners history and the character of the material studied it might even suggest the duration of the holiday. The result might fragment the academic year, yet the current furor over flexible scheduling is a first admission of the value of such more complex approaches.

There is one caveat that must accompany such dreams and predictions. Changes in educational process will have an effect on the style of life and thought of the learner. Even today it is impossible to introduce "causal thinking" or the inductive process without changing the outlook and even the social class behavior of the learner. As we have noted, there is reason to evaluate the effect of individualized programmed instruction especially if there is prospect of its use without the balance of group interaction. The probability that the literal-mindedness of the computer can be used to reinforce the necessity for precise formal description of the problem and the student's steps toward the solution should be examined for positive and negative aspects. The use of programming languages clarified certain fundamental concepts that are built into the languages, such as variable expression, function, and equation. We should understand the meaning of the assumptions. With the prospect of such effect, it is important that some effort be devoted by behavioral or social science teams to understanding the psychological and social meaning of such change. Part of this report has been devoted to that purpose. More time and information is needed.

Effect on Psychological Processes and Values

The Seminar and other investigation by the authors suggest a number of areas in which use of the computer for instructional purposes may have discernable effects on the "style of thinking" of the learner. The full nature of these effects should be determined, and the findings utilized in the making of decisions about CAI.

Humanized and Dehumanized Education

The most frequent question about "ways of thinking" and CAI relates to the so called "dehumanization of thinking". It is not yet clear that this can or will be a product of CAI. Because of the concern aroused there may be some overcompensation. Programmers have on occassions attempted to "humanize" the computer, complete with a cheery "Good morning" to a heartfelt "Come see me again". The question has been asked: does this personalize the relationship? If it does, will the child develop a somewhat warped view of the relationship with the terminal? The panelists asked whether it is sufficiently conducive of the "tool", as opposed to the "teacher", perception of the computer for the terminal to assume the characteristics of "a man in a box". Perhaps future generations of learners will regard these perceptions as similar to the tendency to give the family car a pet name. For today we do not know.

Mastery

The trend line of CAI is a recent segment of the shift over the centuries from muscle to brain power. The advent of a new "lever for thinking processes" is certainly a factor to be reckoned with. It may set the style for an even more significant step, the advent of the heightening of importance of mastery over the intellectual processes, the discovery of new ways to acquire and develop new knowledge and new ways of obtaining knowledge. This characteristic has largely been associated with some segments of the upper middle class. Its spread to other parts of the population will have profound effects on the knowledge revolution and social mobility. For the learner from the lower socio-economic group the fact that it may be acquired with a minimum of interaction with a socially different group may promote the motivation for and the development of this competence. We are, nevertheless, faced with another question and decision point in this seemingly desirable formulation. How will such changed and improved problem solving be used by the individual who has not developed close ties and interaction with the human teacher? Even this seeming turnabout and caveat should not lead to any conclusions until we have investigated further. If, however, the implications of the several questions in this paragraph have validity, they should lead us to concern with the development of total and well thought out educational systems rather than reliance on technology or the teacher individually.

The Demand for Logical Thinking

A most powerful argument for the use of CAI is the computer's requirement of precise logical and frequently analytic thinking by the user. If this is true, an immediate plus is scored for certainly this is a weakness of many of our learners. However, where will it lead us? Dr. Kropp suggests that the less than precise answer accepted by the human teacher may have another purpose and a higher order of priority.

Current use of CAI establishes a qualitative change in learner objectives. Properly programmed, the computer places its greatest emphasis on achievement rather than speed or lock-step pacing with other students. Such a system should tend to enhance individual differences and divergent approaches to solutions of the same problem. The ultimate interdependency of these two objectives, precision and creativity, should be explored. Without it achievement is even more conforming and divergence is even more troubling and will be negatively reinforced.

Inductive and Deductive Thinking

Dr. Meierhenry directs us to another potential and very significant change in style of thinking. Addressing himself to the BB&N case study method in teacher training, he notes that this may help to overcome the strongly deductive tendency of teacher training. He states

> "Some specialists believe that a major weakness in teaching and in education has been the almost complete reliance on the deductive rather than the inductive approach."

Effective use of Socratic or inquiry methods may modify this educational bias. The development of programs clearly designed to achieve balance in modes of thought is probably necessary. If we look closely we may be able to attribute to this bias some of the current limitations of teacher practice. The failure to obtain individualized perception of andprescription for each child may derive in part from this source. The teacher is generally not prepared to hypothesize, or conceptualize. We may also find, at this door, the reason for the failure of education to produce a sizeable number of educational researchers.

The Teacher as a Model

Even more basic is the enduring role of the teacher as model for the learner. In this case both the human teacher and the computerized teacher assistant can provide a demonstration of a powerful tool that is too often lacking in education. Close consideration of the several styles of program development is critical. Too heavy an emphasis on either the drill, the tutorial, or the Socratic methods may produce unbalance that will interfere with the achievement of the broader goals of education in the future.

The Pluri-Terminal

Dr. Carpenter calls attention to an important decision, the overcommitment to individualization, that may have already been made but which we may desire to reconsider. In suggesting the use of "pluri-terminals" he highlights the apparently complete emphasis on individualized instruction. During the survey by the authors who were also concerned with this problem only one (Santa Barbara California High School) very small and inadequately supported project, had displayed interest in group problem solving. Carpenter suggests that learning may be optimized in social interactional situations. It is also true that much of the problem solving of our time in industry and in research takes place in groups even though the closure may still be that of the individual. To fail to provide cooperative settings and values for problem solving may be a throw-back to an earlier generation. The decision to consider the study of group operation of the computer may be well worth the investment.

The previous point reveals an even more basic question: that of the ecology of learning, particularly computer assisted learning. The computer most certainly provides a massive change in the learning environment and simultaneousley provides an instrument for the study of these conditions. This is developed more fully in the section on research and development needs.

Simulation

One medium for study and achievement of the processes of group problem solving is that of simulation. The playing of group games and the simulation of group problem solving situations provide an effective laboratory for the understanding of basic group learning processes, and even for the question of whether such a phenomenon exists. A closer link of experimental social psychology with education and CAI research would seem to be indicated.

Cognition

Education has gained support from another area of psychological research as a result of the recent explorations in cognition. There has been little quantitative investigation of cognitative style, but there is enough in the literature and in the experience of behavioral scientists and teachers to initiate interest by both educators and the developers of educational technology. Once again the promise of the computer as a research instrument is evident. Are there differences in cognitive style? Are there modalities that can be quantitatively derived and effectively used? Can we, and should we, intervene in this development process in the learner? How can we do so? Are the goals of flexibility and the broad range of skills compatible and desirable? The solution to many of these problems will guide the development of CAI. We are optimistic of success. If this is well founded the potential of CAI as a diagnostic tool as well a research and educational tool are a bright part of the future. Nevertheless, research must go beyond the questions developed to consider the social and human implications of such intervention by this particular kind of instrument.

Aesthetics

Closely related is the need for examination of the role of aesthetics in education. The advent of the computer with its greater capacity for programming and for monitoring makes possible the study and application of the questions of psychological comfort in learning, and the aesthetics of learning. We are faced with the challenge of whether the "beautiful idea", the "sound closure" or the well formed sound image have an effect on learning. If they do, and we can learn the key to preparation of sequence and relationship of materials, then we have a powerful educational tool. Indeed this has probably always been part of the art of good teaching. Can we learn enough about it so that at best we are able to improve the thinking of the learner by sensitization to such considerations, and at least we are able to set minimum criteria for the material we offer to the learner? It is conceivable that the fractionated or unorganized presentation of materials contributes to the destruction of closure and creative learning? Careful analysis of behavioral goals are critical to accomplishing this task. However, it must be remembered that behavioral objectives come in many sizes, levels, and degrees of abstraction. Mitzel and Rabinowitz point out that "Educational functions are not, in practice, fragmented, and it is therefore difficult for teachers to see just how they will go about being creative in a classroom where matter is taught by programmed materials."[188] The caveat is well taken, it should lead us on to the decision to consider programming as establishing the potential for synthesis and discovery. The implications for the motivation of effective research and development in this area are profound.

Values

The new ways of thinking that will confront us as a result of computer use will doubtlessly involve new values as well. Many of the issues we have discussed in this section are laden with value implications. It is probable that we will have to reassess the meaning of work. In our society work is good and leisure is suspect. Education and learning lie somewhere in between. In the economy and society of tomorrow man will probably have more leisure and will doubtless have to pursue learning into his adult years. Furthermore, there may not be a "hardgoods" product in an increasingly service oriented economy. We must consider early commencement of education that promotes the value of educational objectives of service to the self and to other humans. With this as one example, we are faced with the potential for changing "ways of thinking" that will have tremendous impact on the future, some for good, some for ill. If CAI is to be an instrument in this education, the role of the medium must also be considered.

Dr. Schure recommends to us the very fundemental effect of improved communications, data retrieval, and computational systems. The effect of such resources on the style of thinking of man may be critical. Man may stop thinking about minor problems or instrumental steps, chores, and details. He may increasingly be able to concern himself with larger and more abstract issues. A premium may be placed on the kind of thought that is less concerned with obsessive detail and more with the fundamental issues that man may confront better than the computer. To achieve this, however, we must carefully calculate the effects of "The Computer Discipline" described earlier. The computer may require more precision of man. If, on the other hand it becomes a model for this thought, the "Frankenstein Syndrome", that assails so many of our scientists with guilt about the destructive use of their inventions, may have validity in the future. The alternative at this decision node is offered by Dr. Wilson who places a very high value on the capacity of education to "breed" the inquiring mind.

The Handling of Information

One of the great qualitative changes resulting from the use of computers in education relates to the manipulation of information. It has made possible the handling of and rapid access to vast amounts of data and published material.

The Bio-Sciences Information Project at The George Washington University has defined one communications problem as the diffusion of related materials through a large number of publication outlets. A large number of the articles in which they were interested were located in journals with three or fewer related articles per year. This exemplifies the problem of how neither student nor teacher can assemble a critical mass of information without devoting an excessive amount of energy to the search.

The computer offers a beginning solution to the problem and may eventually offer more. Readings can be reproduced precisely when required, either by teletype, CRT or eventually be electrostatic printing. Dial access library research can supplement the sources directly available to the student.

Perhaps there should be a pause before this uncritical pursuit of the model of the book. With new resources available it may be useful to seek to understand the psychological meaning and the process of the book. Do all students want or profit from the same sequence? Are visual methods best for all learning by all people? These are a few of the more obvious questions. They should be followed by others concerning the objectives of a library or an information source. Are they best satisfied by the book as the unity of supply, or the tape, or the 3-D model?

We have discussed in another section one outcome of such investigation. It is the hand-tailored book created from almost unlimited source material and adapted to what the student - teacher team wants to accomplish, in a way that is most conducive to learning by the student. Written portions can be supplied by Xerography, other media can play their role. The final product would be the ideal teaching medium for the given task. This is only an ideal. However, the questions asked and answered in its pursuit may go far toward the improvement of education.

Changes are also taking place in the organization of information books. The role of new systems for information transmission including ERIC, EDUCOM, ENTELEK, etc. also merits attention. How will they be affected by and in turn effect the new educational technology?

Computer Systems and Human Systems

Despite the tendency of all those writing on the subject to present the computer as a single knight doing battle with the dragon of ignorance or perhaps a single dragon doing battle....., it was a clear consensus of the panel that the unit of concern [illegible] the educational system of which the computer is one element as are the other technological contributions. There was also the acknowledgment that even this teaching (or learning) system is part of an educational process or system.

The concern with education as a system seems to demand that we account for all the effective forces in the system. Clearly, investigation is necessary into the many factors that are a part of the system.

It is possible to agree that the learner is never alone, even with programmed instruction. The structure of the program limits or extends him. There are people, things, and relationships in the learning system. Whether the instruction derives from teacher or computer Dr. Wilson reminds us that the third factor is the relationship between the instructor and the learner, and between the knower and the known. The derivative question comes readily. Do we know what the components of the system are? Do we understand the relationships?

Teacher, subject matter, administration, school bus driver, parents and on and on, all affect the end product the learning child. The limits of the forces affecting education may include the books on the shelf at home and how the parents use them. All of this is part of the ecology of education and part of the system of education. Not all can be controlled or even known, but we should seek greater knowledge than we have now and the computer offers a tool to handle the expanding store of data.

We discuss in another part of the paper the non-instructional uses of the computer in education. We state that its establishment as a managerial or statistical tool will prepare the way for CAI. Considered in another way, the assembly of information on health, attendance, schedule, parental occupation, class size, and previous achievement is all part of the educational system or can be. The ready availability of such data to teacher or researcher provides a clearer picture of the educational system and it is this understanding of the ecology of learning for the child that can be employed to improve that learning. This is a global concept with many practical applications. As we will see, it is also fraught with dangers to the privacy and the individuality of the learner.

From this point of view, many questions may be derived. Dr. Duhl asks that we study the"mix of education" by using the computer to monitor. Sr. Schure has provided a system with such a capability.

We believe it is also necessary to study the student response as a way of understanding a vital element of the system. Dr. Kropp points to the primitiveness of our understanding of educational systems, and asks a long list of questions.

It is the recommendation of the panel that whether we concern ourselves with student-computer interfaces or with student-teacher-administrative computer interfaces, that we not fragment the essential quality of the pehnomenon: that learning is the product of a system which once analyzed must be resynthesized to be used effectively.

Recommendations were offered for pilot studies of educational units in the field so that the taint of the laboratory and the Hawthorne effect might be removed. It will be a long time before CAI can be de-Hawthornized, but this is no reason why functioning units of education cannot be studied in vivo by using the data-gathering potential of the computer.

The Computer and Testing

The purpose of a test is to determine what progress the learner has made according to a given criterion. Sometimes the standards are objective, sometimes less than precise. In either case a considerable amount of the class time of the learner is devoted to being tested. One of the advantages of CAI resides in the capacity of the computer to observe, from moment to moment, the progress achieved by the student and provide the teacher with such information. Even one hour per week at the terminal for each pupil can provide the teacher with a large amount of information without cost of class time. Much of this can be accomplished through the use of what Mitzell describes as "imbedded items", units incorporated in the lesson, that provide information about the rate of achievement of the learner.

It is possible that with such a system, or by adequate understanding of levels of achievement we may be able to report progress instead of grades. The implications of such a step are considerable in terms of pupil motivation, mental health and efficiency. The area requires extensive study now that we have the alternative of choosing between systems.

The Continous Audit

The availability of a continuing record of the learner's progress suggests a unique, powerful, and possibly troublesome development. If progress through school both in individual subjects and in education generally conceived, can be viewed as a continuing process rather than one that is fragmented into grades and varies according to teacher, then we have the capacity for a continuous audit of the learner's development. The computer monitor particularly where coupled with CAI would seem to have this potential. Not only can it record progress in a given course but it can, by imbedding related items in a number of courses, cut across the "departmental curtains" and note progress in both specific and general skills that are not confined to a given subject or content area. Such processes as latency time, deductive or inductive processes, vocabulary range, and even more complex skills could be tracked in a manner that would be impossible for the human teacher. In addition to its role in recording the progress of the learner, a continuing assessment of aptitude, interest and attention could be maintained thereby giving the teacher information on which to base her prescription and scheduling of the student's later assignments. It would provide the basis for an individual strategy of education for each child.

Not only can we learn about the progress of the individual. Such data can assist in the evaluation of teaching materials, computer and instructional television programs, and a number of the aspects of the new technology that require validation in the field. We may even be given warning of when the utility or effectiveness of a given instrument begins to decline.

Thus it appears we have the potential in the mid-future for a vast improvement in "educational bookkeeping" for the individual child as well as the system. However, it is not without its dangers. As we observed in the section on privacy, such an audit has the potential for collecting and retaining data of such a personal nature that it may violate the right of the individual and the family. If these dangers can be guarded against, the potential for good, of this new instrument, is inestimable.

Counseling

Urban schools today are in a process of rapid expansion. However, growth in the number of students is not matched by a proportionate increase in the number of counselors available to help these youngsters make appropriate course and career decisions. The sheer record-reviewing problem can be the despair of a counselor conscientiously trying to guide students towards choices suited to the needs. talents, and desires of each. Here is a clearly valuable use of the computer in education. Scholastic, and other pertinent data can be made speedily available to the counselor along with current information on college and employment requirements, short and long range career opportunities.

Student use of computers for counseling could be equally promising. We know, for instance, of the gap between what is taught in school and on-the-job requirements. Age-relevant, skill-relevant simultation of work settings, including the problems, style of operation, pressures, etc., involved would allow the student to explore realistic possibilities. He could learn, for example, about the interpersonal skill and patience required of the administrator; about the current market, pay scale, and geographical demand for engineers.

However, student use of the computer for advice based on probability models must be carefully evaluated. As Dr. Lewis has pointed out, there is serious potential for both social and individual damage if we operate on statistical predictions from the past. Unless the computer can be programmed to be sensitive to changing social and economic conditions, as well as to the determination and "guts" of the individual, it may prove a poor counselor. Programming for student use of computers for counseling is a complicated area which will require extensive and imaginative research.

Changes in the Organization of Education

Each of the great changes in history has produced its effect on the shape and organization of the school. Some have been major such as the shift from the little red school house to the skyscraper school, that followed urbanization, and the school bus. Others have been more subtle but no less pervasive. The computer has already left its mark on the school system in the form of more efficient housekeeping methods, and this effect has barely begun. Other changes may be products of the age of the computer though not related to its use.

Perhaps the most general effect will be on the ecology both internal and external of the educational system. As Dr. Kropp describes it we may expect effects on the organization, power structure, roles of the members and on the effectiveness of the agency.

The capacity of the computer to handle vast amounts of data carries with it the capacity for management and control of larger and larger units. If efficiency can then grow with size instead of suffering as a result of it, we may expect school systems and educational networks to grow larger, at least until they encounter political or social resistance to their size. Dr. McLoone suggests in his backward look from the 1980's that "some systems became sub-systems of larger systems". From there he projects the development of highly efficient yet massive organizations. Dr. Wilson and Dr. Meierhenry are concerned about the development of such a monolithic system and even more with who will control it. Yet both see, as well, the possibility of increased local flexibility, deriving from computer use. The two poles offered are a universal dilemna, latent in the use of the computer.

It is likely that the improved nervous system the computer offers will result in similar trends in health, welfare, and other aspects of government. The community (and larger unit) data gathering and planning potential of the computer will probably result in data banks, integrated purchasing, demographic accounting, and other centripetal forces. From them may also derive the greater community capacity to be concerned with the needs and anticipate the problems of the little people within the system. Thus for both school and community the problem is a common one. Indeed it is possible that, as the relationship and importance of the educational system to society becomes more apparent, the Schure and Meierhenry concepts of the community school will come closer to reality.

Dr. Schure illustrates his concept with the "zero reject" tradition to which the educational management system would be attuned. No product of the educational system would be rejected, but instead a way of educating him devised.

In more than a few cases conventional schooling will not prove effective. We have already had evidence of the need for alternative educational systems. If we seek to approach the zero reject ideal, a somewhat wider range of institutions and curricula may be expected to arise. The only alternative is to ask the individual to conform to the narrower system of education and there are limits beyond which this is unacceptable or impossible in our society.

In the service of such needs we have already established alternative educational agencies such as Head Start and the Job Corps. Experimentation is underway with early childhood education programs in day care centers, and even more adaptation and reaching out may be expected.

The effect of such changes in the loci of education will doubtless produce some changes in the organization of the educational system. Even more changes will be accomplished when we begin to standardize in-service training and education programs in industry and adult education systems. While these trends may not require or even be triggered by the computer, they will be hastened by the need for more skilled manpower in a computerized society and the social objective of education for all. They will be facilitated by the advent of CAI which can extend and diversify our teaching potential. CAI offers still greater potential for changes in the organization of the school. If individualization continues to emerge as a primary goal we may expect "flexible schedules" to follow, and indeed they have already become controversial. In any event, the relationship of one teacher to one class will have already been demolished by instructional television, CAI, and related technology. Reorganization of the supporting system and the introduction of more flexible curriculum development methods and agencies may not be far behind.

We have agreed that computer management will most certainly precede CAI into the schools. They will provide a valuable tool for studying and operating the system. The reciprocal bending of school needs and school administrative systems to each other has always been true. What unbalance will the computer produce in this system? Investigation of the effects of existing computer systems in both education and industry might well be undertaken to detect the direction and quality of change. Will the teacher become a more salient or a more subservient party? Will curriculum development dominate? Will the principal lose his feudal freedom? Will the county school system itself be absorbed in the metropolitan or state system?

Dr. Schure describes the need for logistic and economic avenues to the goals of consistent performance in socially valuable activity. He suggests that to accomplish these objectives all the tools available within sophisticated business management, relevant science, and applicable technology should be utilized. Such an effort requires more than the preachment, but will require the establishment of a system probably within the government and perhaps paralleling or even resembling a "National Institute" that could develop methodologies for such coordination of science, technology, and management.

Educational laboratories and policy centers have already been established in this service. Unless one or the other of these research and development operations can be modified toward more inclusive organization forms, involving industry, voluntary agencies, etc., they may duplicate each other. More society-orientated mechanisms following the model of the community school should also be considered.

With regard to CAI, we may have need of a machinery to study the continuing social and personal effects of the computer as well as changes in the mediating agency, the administration of education. Such a machinery may be a cooperative venture of industry, government and education modeled after the educational laboratory but more intensive in its nature and style. The proliferation of divergent modes of study is perceived as healthy. We have been fortunate in education for as Mr. Thomsen warns, " ... our democracy is quicker to support the development of new technology than to concoct the organization systems to effectively engage them". This may not always be true.

Horizontal Systems and Vertical Systems

The concept of the educational system with the need for systematic analysis is growing in acceptance in education. There is another system of equally great importance that has existed in one form or another for several hundred years. Yet it has never been adequately developed, and proves a source of frustration and waste to student and society. This is the vertical system of sequence of education from pre-primary to graduate and post doctoral education. It is bedevilled with poor dovetailing at the linkage joints in elementary school to high school, high school to college, etc. Even between the separate grades there is a review period to attempt to assure that all students start at the same point, or at least with a baseline of information and skill --the result may be one quarter of each semester wasted.

The efforts to establish a vertical system in education have not been entirely successful. One resultant has been the reduction of much high school curriculum to what might well be learned in later elementary school, and the reduction of the college years to the equivalent of many European high schools. Further, there seems to be no place for vocational education in a system whose values lie with academicia, and even less a chance for the vocational student with a change of heart or a late spurt of ability to rejoin the academic sequence.

CAI may not be critical to the improvement of this situation. However, it offers a period of change and reassessment, and considerably improved resources with which a smoother and more efficient vertical system can be developed.

The systems approach is necessary to learn what our objectives for development and for each level (if there are discrete levels) should be. Perhaps it will yield a series of developmental curves or configurations, and suggest that there is no one way to the Ph.D.- a fact that we know but do not employ. That the pace of development need not be uniform is evident from the range of age of Ph.D.'s from 16 to 75. The success of the post war G.I. student offers some cues about the value of experience, maturity, and motivation - we need to know more. In short, a series of studies of educational development matched with the characteristics of the vertical system in education are needed. They may even suggest that the sequence of course development need not be the same for each student, for one modality mathematics might well precede the social sciences. For others it might follow more comfortably once the person's role in society and the nature of society are more perfectly understood.

CAI offers as a basic contribution its capacity for monitoring the achievement of the individual learner: the ability to know when he is ready for the next step, and to assist him, without disturbance to other learners, when he appears to be in need of assistance. We have noted elsewhere that it also permits him to follow an idiosyncratic line of development while still satisfying basic requirements for competence. Dr. McLoone has spelled out the extreme automation of such progression by the learner. Without going to the "automated diploma", we may yet permit the more natural, efficient progression of the student through his education without the fetters of the prefabricated "Procrustean beds" called grades. Or even if we maintain the fiction of grades, the student may be freed of their more arbitrary restraints.

These issues are already of some concern to educators. It is likely that experimentation and study will increase in scope, pace, and imaginativeness and that with an assist from the computer we may break out of the lock-step in vertical educational systems.

The role of systems analysis and CAI in feedback to the student about educational systems should also be considered. We have many formulations about the system. Dr. Kropp describes the basis for learning as the learner, the stimulus conditions, content, the media and modes of stimulation, and the phasing of events in the system.

These are basic to both of the systems we have considered above. Others, examining CAI as a system, consider the instructor, materials, machine, technologists, technology, and above all the learner and his personal goals and prior experience as the system for CAI. Dr. Carpenter adds the essential elements of timing, phasing, and patterning. There is little reason why these cannot be brought to the awareness of the student at some stage of his development. We try to teach the theory of numbers to children, and eventually they may learn social studies to help them live in society, and even to know the philosophy of knowledge. Yet the principles of the educational environment in which they live are kept a dark mystery. Perhaps if more students knew the mystery, education would hold greater allure for the potential teacher and scientist. Certainly it could provide greater awareness and mastery of what they are doing.

If students were armed with more of the basic units and knowledge of the process of teaching and learning, education might also develop more strength as inductive science. We will not learn about new systems of education and develop more creative ones unless we use systems analysis more inductively. The research products of systems analysis must be used synthetically, to develop new theories of education rather than a simple reductionism to objectives on the basis of pre-existing theories of learning. If education provides the model and if students learn to think this way, we may expect growth in science and in the science of education.

Changes in Teacher Population, Role and Training

What kinds of teachers will make the best use of CAI? This is almost as important a question as how we must adopt computer use to the teacher. It is critical because we must understand what changes will be needed in the university and in-service education programs for teachers. It also raises questions about what kinds of ancillary roles for non or paraprofessionals will be useful or required in the emerging system of education.

Some of the questions and issues are direct, others less so.

1. Will more men be attracted to teaching? With what effect?

2. Will there emerge the new role of teacher aide, educational technologist, etc? Will this be a pathway to teaching or a new function? The teacher aide as employed in some new educational systems serves the useful additional function of bridging social class and communications gaps between teacher and student. How can such workers fit into an educational system in a manner that has survival value for the teacher, the aide, and the system?

3. The advent of educational technology and improved communication has already suggested the development and flexible use of master teachers and, as Dr. Schure has suggested, the periodic participation of non-teachers in the educational process; i.e. a closed circuit television system or videotape presentation of a famous artist or scientist could be immediately available to a teacher. Such material could either be part of a programmed system or summoned up opportunistically. How we will use them best and what problems this will produce remains to be determined.

It has been a basic assumption that the adoption of the computer in education, either as bookkeeper or instructional aid will produce changes in the educational system. Several of these will relate directly to teacher activities and roles. This will constitute a significant portion of the system's study that should be undertaken. Changes in the tools available to the teacher, in the kinds of teachers, and in the functions of the teacher will doubtless lead to changes in both formal and informal staffing and organizational patterns and in the teacher's perception of himself and his role. The effects of several changes should be considered.

1. Computer monitoring of the teacher's prescription and the learner's achievement will make the teaching process somewhat more public. At least it will be more subject to review by supervisors.

2. The teacher will have greater resources available for learning about his students. Periodic print-outs of performance and eventually the analysis of response patterns will be available. In addition, the

substitute teacher or the teacher at the beginning of a semester can have available a rapid briefing on the current status of each child. These might include achievement, trend lines, specific problems, etc.

3. The use of the computer will allow the teacher and the teacher trainee to keep in mind or at hand a larger number of the variables involved in teaching and learning and can provide a model of the instructional system. Thus equipped he can make creative changes with increased awareness of possible implications or effects. Dr. Meierhenry sums up our hopes:

> "It would be hoped that teacher education could become a highly creative and individualistic process as a result of the students being provided with many opportunities to interact with a wide variety of problem situations presented by the computer."

Training.

Perhaps the most needed and important of the changes involving teachers will involve their pre-service and in-service education.

One early study will likely concentrate on teacher selection as it has taken place and as it might in the future. There should be abundant information available, even without CAI, about the effects of innovation and change on teachers and who makes the best teacher under what conditions of training and employment?

The commitment of education to new problems or renewed involvement in old ones also requires investigation of optimal teacher training and personal requirements. The problems of education in the central city are an excellent example of the challenge to education. It is a fair hypothesis that in addition to teaching skill, the central city teacher will need added training in cultural anthropology, group dynamics, and human motivation and will need to come armed with a fairly intact ego structure if he is to succeed. Dr. Lewis has specified more effectively the needs and the character of this educational challenge.

Some critical elements of pre-service training should be considered.

1. Dr. Meierhenry has discussed the tendency to deductive modes of teaching in the teacher. The school of education should be the first line of the effort to diversify the logical approaches now commonly used. Both faculty and student body need to be alert to such problems. Such changes may require new and unique courses or curriculum modification. CAI will help, since it has value as a potential source of improved problem solving in the classroom. It can provide:
   a. improved research in and out of the classroom
   b. a more effective model for the learner.

"The tendency of the educator to operate deductively

> results in his failure to formulate theories because as a rule he does not create or test hypotheses based on his observations. As a result few formulations are made about the process of learning in the field and little theory is generated. The development of teaching items with more inductive modes of operation, trained in schools of education, and passing into the ranks would assume a new role. They would formulate new and unique curricula and possibly school reorganization. This is underway in some places."

2. We have discussed the capacity of the computer to help the teacher be more sensitive to, and have greater control over, the system of education. It will also assist prospective teachers to become familiar with the concept of instructional systems, including the teacher-computer-learner configuration. It is possible that simulation via computer or ITV will permit the kind of examination of and preparation for the system and its components (including the teacher) that heretofore have not been possible.

New York State is already involved in feasibility studies concerning the teacher educator.(59) Dr. Kropp has dealt with the problem of change effectively in his paper. He is concerned with the need to know what kinds of schools will be needed, and where they will be required. At this time, there is a lack of concensus in education. However, there is the need for study and planning to apply the best "mix" of specialists, both for training and to offer a model to prospective teachers.

An important aspect of teaching rests on the social basis of meaningful education whether in low income areas, or in what have been the leadership areas of the country. Each of the panelists was concerned with this issue. It highlights the need for the extension, to a larger part of our learner population, of the need for new knowledge rather than simply the acquisition of things or even "facts". The expansion of the human intellectual process that is potential with computer assistance may create the invitation to such development by young people in the future.

The Process of Innovation

Dr. Wilson describes the schools as "the despair of the innovator". She mentions three major innovations in education including the first generation of instructional technology. "Yet", she observes, "despite the amount of publicity given these innovations and the examples of a few schools and school districts given national visibility, not much change has taken place in the rank and file of classrooms in the nation."

In a recent Newsweek article, a similar note of despair was reflected by "the future planners" who bemoaned our inability to avoid pollution, congestion, decaying cities, etc., despite our vast new technology.

Both Dr. Wilson and the planners are disheartened by lack of progress that comes in response to what is desired by man. Neither a shiny glass building nor a shiny computer are the objectives of man. It would seem that a clean environment and an effective curriculum are closer to the precise objective of the humanist and the educator. Even if efficiency is demonstrated the effect of new product or process on a man's way of life may be partly determining of his acceptance of it. Dr. Kropp makes this point even more precise:

> "Many innovations having considerably less potential impact than CAI were stillborn because the innovators failed to take into account their probable effect on the host's organization, power structure, roles, sociological and psychological forces and sources of human satisfaction."

He warns that each of the dislocations produced must be dealt with, if not directly then by some adaptation to restore a smoothly operating system.

Dr. Meierhenry suggests a complementary approach, that the computer be used as a way of "solving a wide range of problems which currently are difficult or impossible to solve."

The value accomplished would be the same. It would be to smooth and make more effective the system of education.

This seems to be what has begun. The computer is rapidly achieving a foothold in some educational systems. They are the large and complex ones that have for some time been tripping over their very size and complexity. The introduction of a device that can speed record storage and retrieval and budgeting and planning a hundredfold has been a boon to the harassed educational managers.

Dr. Schure has recommended the introduction of the computer as a monitor and as an instructional management aid. In the face of the complex task of instructional organization and management required in a large school with a modern curriculum another solution to a critical problem is being offered.

Schure and Lewis believe that innovation will be limited by the intensity of concern about it or its absence. The mechanisms described would seem to support this hypothesis. If the gatekeepers perceive the introduction as excessively traumatic or disruptive it will be delayed. If it solves existing problems, it will be embraced.

Who are the gatekeepers? What measures will they use to evaluate acceptability? How can the advantages and disadvantages of the innovation be most accurately presented and demonstration?

Our panelists have discussed many of the forces affecting the acceptance of the computer in the world of education.

1. Savings in man-hours and boredom

2. The ability to examine new complex configurations and to check other data to determine whether these configurations are valid and repeated

3. Capacity for effective intervention to improve learning

4. Capacity for multi-sensory presentation of material

5. Capacity for analysis of response

6. Capacity for feedback

To these must be added the more subjective or personal changes described earlier. One of these is the fear of dehumanization, the destruction of the arts and values, and the loss of sunlight and air. Dr. Wilson suggests the need for more direct sensory contact between people and with the environment in order to counteract the potent artificial environment created by electronic media.

Such a fear will be warranted if we do not make wise use of the new media. Yet it requires some perspective. One may sit in his office looking at a print from the neolithic cave drawings of Lescaux. Down through the ages can be heard the cry of an elder voicing the fear that these artificial daubs of iron pigment and blood, simulating a bison, will soon drain youth of its skill, and the hunt of its vitality. Yet this is the very parent of the art we seek to preserve. This was a technology, an art form. One must ask, is the skill of organizing a problem and presenting it via the media in the way best designed to produce closure and learning less an art? As we have observed elsewhere in this paper a wedding of esthetics and technology can increase the livability of a house and the "learnability" of a principle.

Perhaps we must learn how to demonstrate the beauty of the technology that achieves its function in an esthetically satisfying way. Perhaps the divergence of art and function can be resolved in a way that resolves as well the fears of those who are concerned about change because of its threat to value and beauty.

Some also fear that CAI will replace the school, or at best bypass it. Dr. Wilson sees some merit in bypassing the school in those functions that it cannot master. She favors, as well, the effort to change the school directly. She suggests the setting up of a kind of push-pull mechanism of change vs. loss of a function to effect the desired goals.

On a more basic economic score there are those who note the rapid pace of computer development and fearing to commit themselves to an obsolescent system want to "wait for the home stretch to place their bets". We are faced, thereby, with a problem of financing and organization. It is possible that leasing or time-sharing offers an alternative. In addition the necessary steps toward equipment and language comptability and the establishment of sound criteria will ease the responsible concerns of those administrators who do not want to commit their agencies to a blind alley.

There was general agreement among the panelists that even in the area of innovation, systems analysis broadly conceived would be effective in locating most of the "hang-ups" and bottlenecks, that it would improve both CAI and the educational system and in so doing would facilitate the process of innovation.

The basic objective of the educator is not to introduce CAI. It is to improve curriculum, the cost benefit ratio of the educational operation and the education of the child. Therefore, to the educator the goals are basically those of educational improvement, rather than innovation per se. If the innovation can achieve this end, and if this can be made known to the gatekeepers, it will be accepted.

Research and Development

One of the speakers at the briefing for the seminar recalled a discussion between engineer and scientist that culminated several years of joint work with the statement by the engineer that "If your group will tell us what you want we'll make it". There is something of Bronfenbrenne's "mirror image" conflict in this situation. Over the years the hard scientist, the behavioral scientist, and the educator each seem to believe that the others have mysteries which if revealed to him would make communication and problem solving simpler. To a degree this is true. The psychologist and the educator may never fully understand an integrated circuit, the engineer may never completely appreciate the complexities of cognition or the art of the teacher who will accept an incorrect answer to motivate a student.

However, if R & D in educational technology is to progress it is unlikely that it will do so best with an arrangement that allows each to nurse his own misunderstanding and assure himself that "everyone else is out of step". While this is perhaps an exaggeration, it is true that there is insufficient communication between the three basic professional modalities that contribute to this field. Only in a few centers have we encountered engineers, scientists, and educators working in the same building with continuing dialogue and even the "small talk over lunch" that contributes so much to real communication. It was not an accident that we chose to visit several of these settings. There would seem to be no particular organizational pattern that forms it. One was a university R & D center, another a non-profit, and the third a profit-making enterprise. J. R. Gentile states his view well in his summary of communications problems:

> "Defining communication as all of the procedures by which one mind may affect another - which includes music, art, education, and automatic equipment - there are three communication problems to be solved: the technical problem, the semantic problem, and the effectiveness problem.
>
> "Phrased as a question, the technical problem is: How accurately and rapidly can the symbols of communication be transmitted from sender to receiver? For CAI this is a hardware problem dealing with the technology of the computer (and, of course, its programming languages) and input-output devices.
>
> "The semantic problem, asking how precisely the transmitted signals convey the desired meaning, is concerned with the identity or satisfactorily close approximation in the interpretation of meaning by the receiver as compared with the intended meaning of the sender. For CAI this is the problem of writing instructional programs.

> "The effectivemess problem is concerned with how effectively the received meaning affects conduct (changes behavior) in the desired way. This for CAI is the problem of learning and the measurement of that learning.
>
> "Despite the fact that these three problems are typically attacked by three different professional groups (the first by engineers, the second by educators and linguists, and the third by psychologists), these are by no means unrelated problems. CAI offers a unique opportunity for these disciplines to pool their efforts toward the common goal of solving the problems of educational communication. An excellent example of a multidisciplined matter interface of interaction, is the program beginning at the University of Pittsburgh's Learning Research and Development Center."

Reliability

The often described advantage of hardware development over software was not quite so apparent when we settled down to a discussion of problems. There was a repeated use of the words "unreliability" and downtime" by educators and scientists. One stated that he would refuse any hardware unless he was given two of everything, a bit like a dual brake system. One medical school complex is contemplating the installation of two full systems with full parallel programming for each in prospect. It is somehow believed that the unreliability is a product of the engineers emphasis on bigger and faster equipment.

At the same time the engineers assure us that the smaller and more compact the equipment the greater the reliability as well as speed. We can only assume that both points of view are correct. That the new equipment is better than the old would seem to be true, as explained. However, it is also likely that the curve of promises and expectations offered to the educator has gone up more steeply than the curve of performance. Thus more is being asked of the computer and even more of the linkages by the terminals and by the programmer. We are reminded of one situation, seen first hand, where the downtime was the product of an exposed alligator clip that both teacher and pupil accidently kicked open every time they passed it.

Such disagreements and problems can be expected where three high-spirited and confident professions are harnessed together. We would submit that more time spent together would convince the educator of both the hardware capability and problem, and demonstrate to the engineers the urgency of reliability in an operating school setting.

Hardware Futures

At this writing it is possible to peer tentatively through the murky crystal ball made up of a composite of industrial annual reports, the pages of the Wall Street Journal, several technical journals and the Entelek cards. Advances in both computer and auxilliary equipment seem to be accelerating. The third generation of computers are rapidly evolving into an improved third generation and a tentative fourth generation. Clearly speed will be increased as size is reduced. This is the formula, essentially they are two sides of the same coin as Dr. Robinson explained in his introduction to our briefing. As the speed and power of the computer increases, the interfaces with other parts of the system must improve or we have nowhere to go except to more time-sharing.

However, the auxilliary equipment development has not been standing still. Sophistication of new terminals is increasing. We will only mention a few of the hundreds of potential new techniques only enough to stimulate the creative imagination of those who would like to increase the armementarium of education.

Whole new systems are in prospect, developed around communication satellites and microwave transmission. These would permit transmission, perhaps at reduced cost, or programs for school and home instruction. It is unclear whether direct transmission to the terminals is in prospect in the near future or whether rebroadcast from ground stations will be necessary to funnel the material into local terminals. Instructional television is clearly in prospect and at least one satellite manufacturer is discussing the two-way communication system necessary for CAI. Power capability will probably be determining in the latter case.

We have heard presentations of the possibility of a 5 to 10 year satellite capable of relaying information at a cost of $1.00 per student per megabit. The feasability of this we must leave to the engineers.

Other basic areas of development include the use of lasers, improved microwave transmission, and electrostatic printing. These offer potential ranging from producing hard copy at the terminal, without moving parts, to the production of three-dimensional images (holograms) that would vastly extend the capability for display of material and concepts. The development of character recognition equipment promises computer ability to read hand printed materials very soon, and script in the future. The use of electrofluorescing surfaces promised advances in both recognition and display.

One of our authors, Dr. Schure, even suggests eventual gains in biomedical research by the development of transducer-like materials capable of simulating the function of aural, optic, and other nerve tissue. Such advances we offer only for the sake of perspective.

They are likely to be part of education in the 80's.

Potential improvement in computer functioning are not limited to hardware. Dr. Schure believes that computer generation of material by algorithmic applications is possible. Whether it is for practical systems would seem to depend on how much we can learn of the characteristics of the several learning or educational modalities. The burden of R & D in CAI will be both the technological improvement and its integration into an effective system for the facilitation of learning. It is a case of if both the scientists and the programmers "do their homework" we may achieve such a goal.

Summary of R & D Considerations

A new wave of R & D is just getting under weigh in education. The need has been established by recognition of the education and information explosion and implosion. The acceptance of the cross-disciplinary approach and systems analysis will enrich it and make it more precise, and the new technology, especially the computer, will assure that it can cope with the demands for data handling.

The need for new theory is another critical element that has been lacking in research. Several factors will contribute to greater emphasis on the development of such new theory. Computer use will make data gathering and handling cheaper and more possible, if not simpler. The spread of the inductive approach will further new theorizing.

There is both a challenge and weakness in the use of the computer in research. With its vast power, we can apply the same theory and the same method to all problems, or we can choose to follow the more promising scientific approach contained in:

a. learning the characteristics or "guts" of a problem or subject;
b. developing the necessary concepts and even theory to deal with those characteristics;
c. determine the appropriate methods or devise new methods to fit the characteristics.

Thus, when we suggest the need for increased study of methodology in educational research, it is a strict use of the term. We need to know the characteristics of our problems, and devise ways to deal with them that are appropriate.

Thus, out of the emergence of new theory and the availability of more and different data there will arise the need for new methodological efforts and new statistical techniques, as well as the examination of some of the old ones.

We are already approaching a need for balance between research and development. A new "theory explosion" may drive a wedge between R & D, or if it is tested via some operational or action research methods it may bring them closer. We cannot predict either the direction or the value to be followed. We do suggest that the wedge not be driven too deeply lest communication break down as it did at one time between psychology and education, or physics and engineering.

We discuss elsewhere the industry-university-education dilemma. There is also its locus in education that must be considered. With computer assistance, a school district of moderate size could engage in its own research and development. It is equally possible that emphasis will shift to larger units, the state, industry, or the Regional Educational Laboratories. The capacity of local and larger units will have been enhanced by CAI and the computer. Where the fates will place the R & D function will depend on financing, manpower, local needs, and at times the nature and extent of the problem to be studied.

The shape of R & D may define and answer another problem. CAI can improve our capacity for "imprinting" the learner. It can also increase his knowledge of how to learn as well as our understanding of his motivation to learn. We can enhance information holding or effective intelligence. The value decision that is made will be affected by and will in turn affect the development of educational theory.

The Problem of Software and Curriculum Development

It is acknowledged by most that one of the great bottlenecks lies in the lack of good programs. Dr. Wilson stated quite directly that while she was impressed by the educative possibilities, she was depressed by the state of the art. Not by the technology, nor by the ingenious languages, but by the limited and embryonic state of the programs currently under development and being field tested. She described them as little more than a marriage between the computer and well-ordered programmed instruction. The panel was concerned that CAI not be limited to the administration of PI through a high powered machine, but that educational elements leading to such skills as advanced concept formation and abstraction be facilitated via the medium.

It was heartening for the panel to learn that starts are being made in more sophisticated use of the computer. It was their conclusion, however, that perhaps the greatest R & D emphasis should be placed on the development of improved programs.

There was some agreement on the need for more emphasis on the development of natural language communication with the computer. The reasons relate both to the desire for local control of CAI by the teacher and learner, and the elimination of constraints on style of thinking produced by the nature of the language. There was awareness that full natural language communication with the computer is remote, but an approach to the ideal with full awareness of the several objectives was urged.

Pursuing the idea that CAI should not be simply programmed instruction led to questions about the implications and directions of individually programmed instruction (IPI).

Some of the panelists accepted the concept of IPI even without schools. Others were concerned about the barrenness of the process, and the loss of the advantages offered by non-programmed activity such as class discussions, outdoor education, and student self-help.

In the requests for fuller consideration of student control of programming, the availability of information retrieval capacity, and group use of the computer there is the concern that IPI alone despite its great capacity for individually tailoring education, makes no allowance for the gestalt of learning, or for the socialization that takes place in education. This last was deemed very important. We have no evidence of the effect of IPI on personality. Nor do we have any situations in which pure IPI is being used even experimentally. However, the panel believed that any tendency to disturb a necessary balance between individualization and socialization at best should be investigated fully before too much commitment is made.

IPI is regarded as an element, not an end in education. It is seen as a way of stimulating the individual's resourcefulness as well as drawing on his unique talents. This freedom with individuality can be regarded as a social asset. It provides the individual with strength to be an active and constructive participant in a social process. However, it is necessary to provide also the social situation in which to try out the strengths, encounter the divergent approaches of other students, and learn cooperative values. Social problem solving using one's unique skills in concert with others was highly valued as an educational objective. As a result there was a careful encouragement of IPI with the qualification that education's goals exceed the capacities of this one valuable element. The model of the congruence of individual and social education remains a consistent one for the panel.

Interprofessional Cooperation in R & D

During the seminar and late in the evening, when feet were up and hair was down some very fundamental possibilities were considered. The lack of communication between the technologist and the educator was seen as another evidence of the "mirror image" phenomenon - The educator doubting the humanity and the reliability of the engineers product and the engineer doubting the systematic quality, the reliability, the "hardnose" quality of the educator's product. Yet here in CAI the need for communication is critical.

Even more there was the feeling that the educator accustomed to the demands for statistical validity of both engineer and behavioral scientist, and unaccustomed to delivering such evidence, may doubt his own ability to "lay a product on the line". He may be wary of delivering a program that expresses and demonstrates what he wants to teach. Further, there may be a modicum of justice in his position. It may be difficult to set forth behavioral objectives in the way that the educator perceives the request.

One of the panelists suggested that perhaps we should not begin until more progress had been made in the basics. Another suggested that progress would be made when we began collecting data from the application of CAI. Whichever is right, it is clear that we need to know more about the nature of individual differences, learning, cognition, the gestalt of learning motivation, the meaning of responses, and a method for analyzing response. Even more we returned to the need for study of the full educational system and its setting.

It was suggested that by studying that full system together the educator and the technologist might achieve the blending of method and critical variables that would lead to meaningful research concept formulation and theory. Research into optimal man-machine relations was suggested. Not the kind that has characterized operations research in the past, but research seeking the potential in man that is elicited by the capability of the computer and the potential of the computer that man, seeking his fullest expression not his minimum needs, can draw from the machine.

Dr. Schure and Dr. Meierhenry have offered approaches to this objective. Dr. Wilson offers a number of related recommendations. Her suggestions for action research with a systems analytic orientation and the development of a curriculum to study the impact of technology on society may be most significant for they provide common ground upon which technology and education can work together and learn together.

CAI and Industry

The futures of industry and education in the world of tomorrow are inevitably interrelated. The increasing dependence of industry on education to produce the skills and intelligence that keep industry moving forward is matched only by the increasing reliance of education on the new technology with the capability of bringing more information and more flexible control of data to both teacher, learner, and administrator.

There are other ties that confirm the prediction of closer relationship. Despite the lethargy with which the industrialization of education has moved, education remains a multi-billion dollar market (estimated at 60-80 billion dollars by 1975) for construction, publishing, furniture, services, and now increasingly for electronics, data processing, systems study, and the other factors derived from the recent surge in educational technology.

The electronics and computer manufacturers have begun to meet the challenge by merger with, or puchase of, some publishing and software companies and the development of working relations with others. According to the description of their activity by industrial managers and our own observation, current steps are not likely to result in the development of monolithic organizations that will dominate the schools. Instead it would appear that at this stage of development a relatively competitive market will exist, if indeed there is any market in that sense. This statement derives from the observation that there are relatively few instruments available for mass application to teaching and even less software for their use. To this must be added the high cost to both industry and education, the unwillingness of most manufacturers to market untested equipment, and the hesitancy of most school systems to make commitments. It remains clear that with one or two possible exceptions, computer systems are still in the pilot state by the agreement of both distributor and consumer.

This pilot activity has resulted in the establishment of CAI projects in a number of typical settings ranging from the central city to the suburban slums to remote rural areas. In these settings collaboration between industry, education, and academcia is extensive and at this time relatively expensive. However, close attention is being given to cost factors as well as to the instructional and engineering aspects.

The effects of the relationship of education and industry, sparked by the computer can be considered under three headings.

1. The economic effects of CAI as an instructional tool
2. The effect on the economy of CAI as a product
3. The financing of CAI development and innovation

It should be clear that the three rubrics are interrelated, however, separate consideration may be merited.

1. Several of our authors have been concerned with the effects of CAI on manpower and training. Early efforts at computerized counseling suggest that, if sound programs are developed, there will be the capability for directing the learner toward a more probable and more appropriate course of education. This would be based on both the abilities and projections concerning the job market. Such a result would increase the efficiency of industry considerably.

Perhaps the greatest danger of the computer revolution is the tremendously increased pace of skill obsolescence as a result of technological change. The computer, linked with imaginative curriculum development (such as the organic curriculum) can produce more flexible and general initial job capability, and the capacity for rapid retraining. In the more professional areas skills can be kept current if the symbiosis of professional and data retrieval tool can be maintained. Scientists, health personnel, managers, and engineers are prime gainers from such a system. It is fairly certain that if CAI enters the university and is used in instruction, people educated to use computers will continue to demand them. In this way a major improvement in industrial and organizational efficiency can be achieved.

The computer may also serve in the further emancipation of women. The availability of an instructional instrument that does not depend on regular classes and scheduled achievement may permit a more relaxed updating of skills and even education of the female during the child-bearing years. As a result when she is ready to resume regular employment she will enter the market at a higher level of competence and with more current skills.

The new technology may also provide a medium for keeping so called "drop-outs" in some kind of educational setting. Once again a higher proportion of skilled labor will be available.

It is possible to discuss other ways in which segments of the population will be upgraded in their job skills by the advent of CAI. Although oversupply is always a possibility, we can only be optimistic about the economic and social implications. As the population increases and industry requires a higher proportion of skilled labor, the alternatives are a) to meet the demand; b) face the growth of a pool of discontented and unskilled unemployed; c) increase the proportion of permanently non-productive members of society. At this stage of our value development, the first alternative would seem to be preferred for reasons of mental and social health as well as industrial productivity. While leisure may increase, it is unlikely that society will be content to grant it to a non-productive class rather than distribute it among all in a way that is personally and socially beneficial.

2. The effects on the economy of CAI as a product may be more

obvious. The computer has become a major product of our industry and software is rapidly becoming the same. The commitment of education to heavy purchases of such equipment can only be significant. Even if CAI is slow in developing as a market, the demand for computers and their associated equipment will grow as the value of the computer in managerial, housekeeping and other non-instructional areas becomes more evident. This in turn will likely create a market for instructional use.

It remains to be unravelled whether the unavailability of software is a barrier to hardware sales or the unavailability of hardware is slowing up software development.

The role of education along with health, communications, aerospace, and leisure in consuming the products of the capital industries may provide a short and a long term cushion against the loss of a market in the event of curtailment of military spending. Whether or not this cushion is needed, the demand by education for an increasing share of computer time will doubtless continue.

It will also have an effect on the development and prosperity of the communications industry. The cost of use of the computer depends heavily on line changes, multiplexing techniques, and the development of microwave and communication satellite methods. The transmission of the information may provide a sizeable barrier to the economic use of the computer in education. It may also be heavily determining of the organization of computer networks and distribution systems. It will therefore be a cardinal issue of public policy to assure economically feasible transmission for the mode of system organization that is educationally and socially most productive.

Federal anti-trust policy is another vital area of policy consideration. As a general principle, the regulations are designed to protect the freedom of competition rather than to create it. While this study was not designed to probe deeply into this area it did develop the problem of potential cross purposes in the need to maintain healthy competitive research and development activity while encouraging the compatability of equipment and computer languages that will also benefit advances in the art.

Another critical area relates to copyright and patent law. While current law may or may not be adequate, we are faced with the question of how to encourage software development, and how to protect the economic rights of those individuals such as teachers who will not be producing the conventional written and copyrightable materials, but may nevertheless be storing equally creative efforts in the memory of a computer.

3. The relationship of industry, the research "industry", government, and the schools, remains one of the most challenging and confused of the policy areas. It seems only simple to suggest that the alterna-

tives lie between government support of research and development, and industry support.

Government support contains the attendant problems of cost-sharing, patents, copyrights, etc. Industry support contains elements of risk that industry may not be willing or able to absorb. Further, it must be noted that public policy and government fiscal programs determine much of the policy of industry. Such factors as the limitation of federal spending commitments to one year, the readiness (albeit commendable) to seek non-educational goals via educational programs, and the vulnerability of education as a budget item all contribute to policy difficulties in an industry that would be expected to make heavier capital commitments to education. In short, the availability of federal dollars for R & D or for purchases may create a market, the unreliability of those dollars may create a problem. It is only realistic to expect that the education budget will derive in part from state and local support and from industry supplemented by an increasing federal share. This would seem to be consistent with the relative taxing powers of segments of the government and the economy.

There remains several alternative forms to such cooperation. 1) Federal support for R & D coupled with some assistance to states, and local areas for capital and operating cost; 2) Industry support of R & D with some federal assistance to states and localities in stabilizing a market for the product.

These alternatives exist but are not really resolved. It is necessary to examine even more closely the characteristics of proposal systems and procurement policies, as well as the extent and characteristics of federal aid to states and the possibilities for interstate and regional cooperation.

These are but a few of the preliminary considerations. They point to a need for direct communication among the several levels of government and between government and industry. Aerospace development may or may not provide a model. In either case we should learn from that and other rapidly developing areas of technology.

In addition to these very high level policy problems, there remain some vital ones involving the remainder of the "knowledge industry". The universities, the "non-profits" and the small profit-making R & D enterprise operate below the heights of industry and government, yet make sizeable, frequently indispensable, contributions. Each is valuable, each has value and handicap arising from its nature. They compete with each other and cooperate as well. The overall question is, how can we assure continuing R & D and adequate supplies of manpower for now and the future? How can we achieve optimal cooperation among them toward the public goal while not jeopardizing their own positions? Dr. Kropp and others view this situation with rightful alarm. Large as some of them are, the "barns and basements" of research in the 70's, the sources of much divergence and creativity, they should be protected or an alternative produced.

Patterns of Employment and CAI

The Utopia and bogeyman of increased leisure time as a result of the advent of the computer are seemingly two sides of a coin. Leisure may = unemployment, depending on the situation. It has been suggested by the Utopians that we will have a new laboring force composed of computers, and a non-laboring force composed of those suffering (or benefitting) from occupational unemployment. Fortunately (or unfortunately) it does not seem to be working out that way. The number of hours of work per week have not declined and may be increasing. If the computer replaces people it also seems to create a demand for new jobs.

There are problems arising from automation and cybernation. It is likely that the pace of occupational change will continue to accelerate. Technological unemployment will depend on the race between job obsolescence and the techniques and the economic and personal motivation for re-education or retraining. The narrowly trained technician and professional will have more difficulty than the worker who has been educated for more flexible or continuing retraining.

As we have observed elsewhere in the report, CAI will play an important role in the determination of the current nature of the labor market and in counselling students and workers about new jobs.

CAI offers an attractive solution to the problem of retraining workers *on the job*. The advantages of gradual adjustment of skills rather than the more traumatic "going back to school" are both economic and psychologic.

Preparation for such continuing education is a responsibility of both the school and the employer. Students will learn that they will not have a lifelong occupation or profession with fixed skills, and they will also learn how to master the attitudes and equipment necessary to achieve their continuing education and competence.

The collaboration of employer and labor union will probably achieve the implementation of this process on the job so that no seniority or advantage is lost to the worker and he is motivated to update his skills.

How rapidly will a generation in education change their occupational activities and direction? Some maintain it requires twenty to thirty years. It is equally possible that the next ten years can produce some very basic changes, providing the opportunities exist in industry and commerce. The next ten years could see the occupational choice of high school juniors and older affected by rapid changes in available employment markets. The very rapid change in the development of opportunities in the computer industry have demonstrated this. Changes in the occupation of those already in the labor market would necessarily by somewhat slower, but would be expedited via the CAI potential in industry. The close audit that the Bureau of Labor Statistics keeps on employment should be taken routinely into account as soon as possible by those responsible for preparation of training and retraining materials.

The statement that most of those who will be in the labor force in the next ten years are already in it is a relative matter. The increase in the labor force during the next ten years may be much higher than it has in the past, particularly should the Vietnam situation release a large number of men currently in the Armed Forces. The Department of Defense is currently developing Project Transition to make use of educational technology toward the goal of rapid re-employment of discharged men into the civilian economy.

There is a question whether the contemporary projections of increasing leisure will actually come true. Instead, will people be devoting less time to employment and more time to continuing education and re-education, as well as to the education teaching and health pursuits that provide a significant new service and production industry. The productive capacity of industry will undoubtedly increase on a per capita basis, but the demands for services offered by individuals will probably increase many times as well.

The role of education as a leisure-time activity is perhaps not the best way to describe this situation. It may be that the use of education during periods of leisure to develop a manpower pool satisfying the next demands of the economy or industry would be the proper way to portray our use of manpower in the future, i.e. something resembling an Antioch system for education and work throughout life.

The application of new and easier education and training methods will, as we have observed, help us reach out to new groups of workers. The senior citizen and the pre-schooler will extend the age limits of our population being educated practically from the cradle to the grave. These new population segments are particularly amenable to education by CAI. The resultant increase in the education industry will probably have the effect of providing employment for many more people. This has been the history of many industries with rapidly increasing consumption patterns. The need for complex educational systems with both human and computer instruction make it likely that this history will be repeated in education.

Educational Technology and Social Change

The relationship of education and its technology to social change is highlighted by Schlure, Wilson, and Lewis and discussed by other of our panelists. All agree that research into the process is necessary and that it should include the identification of meaningful innovative processes. This is a frank realization that it is not only what you do but the way you do it and why.

The most salient element of social change is the current turmoil in education over its responsibility to educate those who do not desire to learn, at least in the manner provided by the school system. We have discussed elements of this problem in a number of places in this report. One solution offered by some of the authors is that we bring education closer to society. Dr. Schure has described the comprehensive school district, and Dr. Wilson has discussed the need to bring CAI and educational policy closer to the fabric of community research. Another suggestion is that we relate it more closely to the needs and motivational system of the individual to be educated. This is not a novel idea to the educator. It is mentioned only because of the unique potential of CAI to assist in this process. Social distance is not a problem at the student-computer interface. Thus it is possible for both teacher and learner to escape for a period of time from these grinding differences that may interfere with learning. Much of this period can be supervised by booth attendants or teacher aides, closer in Socio-Economic level to the learner, and capable of serving as a bridge between the teacher and pupil.

The "organic curriculum" has been discussed as another medium for avoiding the rigidifying of social class, education, and skill. It is a vital concept to be observed and considered carefully.

CAI may serve other purposes in the process of social changes. 1) The education of women may be able to progress without cost to the child rearing function. 2) As we grow more concerned with the involvement of greater segments of our population in the mainstream, we can educate to improve the problem-solving capacities of the less accessible segments. With simulation techniques available and the barriers of excessive social distance diminished, this considerable task may be based somewhat by CAI. 3) With the development of individualized instruction and the consequent minimization of competition in the classroom, Dr. Wilson suggests that new systems of instruction may be established in which older and younger people occupy the same classroom and are able to communicate more satisfactorily. The sharing of programs by parent and child at some home terminal of the future may serve the same purpose or it may go the way of homework and drive even farther the wedge between the generations.

It is even eventually possible that with the availability of terminals in the home or office, a farming out of significant problems to those at leisure or bound to the home would be possible. Such a constructive use of the time of the older, the infirm, or the restricted citizens would have considerable meaning for mental health and social tension as well as adding to our store of applied intelligence. Even more basic would be the shift in values concerning social responsibility that might generalize.

It is even possible that education with CAI will move more toward simulation and gaiming, combining sport and recreation with learning and problem solving. Admittedly this will require very basic technological, distributional, and attitudinal changes but it is interesting to contemplate.

Perhaps sooner we will see more of a shift to a world outlook. As Villard suggests in Technological Innovation and Society, it may very well be that we will shift from national to world emphasis in education during the next 15 to 20 years. We will have to be prepared for a totally different kind and size of problem as well as point of view. Dr. Wilson calls attention to the personnel problems of the future. She expresses the need for a "renaissance man" to be able to evaluate and interpret the use of "the knowledge machine". She suggests, as has Norbert Weiner, the need for responsibility among scientists, engineers, and managers. The need for great wisdom and breadth of approach is evident as it is in any period of social change. If we cannot achieve Dr. Wilson's desired renaissance man perhaps we can seek some system of integrated social-behavioral-technological evaluation and feedback system that would minimize our blunders and our potential guilt. The problem lies in the recruitment of the renaissance mind to produce the theory and the organization to achieve such an objective.

Dr. Wilson's call for a continuing dialogue on the impact of technology on society and the individual probably will not and has not gone unheeded. Perhaps we need to go beyond this and study more thoroughly the instrumental role of CAI and the new technology, as well as the symbiosis that has developed and will continue to develop between man and machine. If we achieve such a view, the term "impact" may not apply so well and technology will not be regarded as a "flying saucer" over which we have no control.

Mental Health and CAI

Psychologists and psychiatrists who have worked closely with CAI perceive considerable potential benefit as well as risk. The fear of the impersonal machine as a substitute for the warm and smiling, or even the angry teacher, has been discussed. There is a difference, but perhaps there are two sides to the issue. In no case do we assume the total substitution of the computer terminal for the teacher.

Special Education.

1. The value of individualized programmed instruction for the advanced or the slow learner is evident. The value of lessened pressure or greater expression and opportunity for such children is evident.

2. The student needing special education may require

   a. idiosyncratic programs
   b. a degree of isolation from distraction
   c. close and detailed attention to his progress
   d. capacity for wide and rapid variation of stimulus input
   e. patience.

Each of these is available via CAI. The potential for "special Ed" has scarcely been tapped.

3. The reading problem and even the early introduction of reading have already come under study by several CAI researchers. The potential for dealing with interpersonal as well as technical factors in reading disability is considerable.

These are only a few of the potential benefits, attendant with some risk, which in time can be minimized by careful R and D.

Self Awareness.

There are more general considerations. One potential value of CAI would be its capacity for sensitizing the learner to the need for self assessment and for providing him with information about his progress and his failings. The learner frequently does not know "what he has done wrong" and the teacher has no time to tell him. He can become more self-aware, more constructively self-conscious, if he has immediate feedback about success and failure on specific functions and problems.

More Time, Better Decisions.

Dr. Duhl describes the increasing role of the school as a substitute for home and parent. He highlights the need for more general and more personal interaction between student and teacher. While superficially this would seem to discount CAI it is also clear that the teacher needs more time for this role. The teacher should be able to attend to the developmental educational function, as well as the adaptive or information giving one. CAI would seem to serve two purposes. It can relieve the teacher of some routine tasks and it can assist, via IPI, the testing function, etc. in the development of an ecologically more satisfying and effective learning situation within the enduring human institution of the school. Such improved learning can only be of great mental health significance. It would seem that this is another area of great potential that requires further R and D as well as creative development by teachers in classrooms.

CAI has several possible weaknesses and strengths that must be dealt with. In considering the potential for alienation of the learner CAI can be, as we have observed, an asset or a liability. The privacy in which to succeed or fail can serve for good or for ill. We must also note the potential for producing optimal social distance between learner and teacher via such a controlled medium. There are many more complex variations of privacy and group interaction that can be controlled by the availability of CAI plus the conventional or unconventional class. In the realm of mental health we can only say that CAI gives more degrees of freedom for creativity to the educator and the behavioral scientist.

Human Rights and CAI

We have discussed in the section on testing some of the possible implications of the "continual audit". Most of the fear is based on what Dr. Wilson describes as the "total recall" of the computer. Once again, the fear is of the potential use of the device, not its implicit character. The terminal will take note of, and the computer will record only what it is programmed to perceive and record. The computer can be programmed to record a great deal of quite personal information. It can absorb such information as police records, membership in non-approved clubs, and personal material from tax records. However, it can also be programmed not to record the source of the data.

It is quite possible that using the "imbedded item" technique, by measuring latency or by a number of other inconspicuous methods, a psychological profile of areas of anxiety and perhaps even more basic personality can be obtained. Such material is usually more valid as group data than it is as a predictor of individual performance, and any effort to use it should be well supported by research. Prior to its use, legal authority should be consulted to determine "star chamber" characteristics and privacy rights.

Much of this information, such as sexual preferences or fears, may be of importance to society as group data, and would constitute an invasion of privacy only when identified with the individual. The group data may produce reservoirs of new and more accurate information of eventual benefit to the aberrant individual as scientific data. How do we reconcile its collection with the threat to his privacy?

Policy Study and Policy Development

Dr. John Gardner, Secretary of HEW recently invited academicians to participate in the process of policy development. He provided a beautifully parsimonious description of policy study:

> "A systematic assessment of social change would aid us in determining our needs, establishing our goals and measuring our performance against these goals."

There are many levels of decision involved in the determination of our needs. The nation has set out on a war against poverty which is essentially a war against ignorance and occupational obsolescence. In our military war we are also faced with glaring manpower deficiencies associated with the failure of either education or society to motivate segments of our youth. We have discussed the accelerating demand for trained and educated personnel and for rapid retraining methods. An inventory of the demands on education also includes the movement toward younger pre-school education and the training of post child-rearing age women and senior citizens. There would also be included the widening gamut of educational demands increasingly including the arts and humanities and leisure pursuits.

Thus the general need for more and improved education is realatively clear. How do we apportion priorities? Do we direct our resources to resolving social problems?, to obtaining the needed manpower? A host of related questions must further define both the need and the goals.

How do we implement the programs to achieve these goals? One decision point involves the choice between 1) heavier commitment to contemporary modes of manpower utilization, i.e. we start training many more teachers to teach in conventional ways. This depends heavily on our ability to recruit them. It has its attendent implications for other parts of the economy and society.

2) A commitment to the increased use of technology in education. This course depends on the ultimate effectiveness and acceptance of such innovation. It also depends on whether we will be satisfied with the other social, economic, and political consequences of such a commitment both within the educational system and in the society as a whole.

Before such steps can be taken we need a mechanism to study the social and personal effects of CAI and computer use in education. Our authors have suggested a number of changes that are possible in the organization of education. These include some tendencies to centralization, but potential for ever more individualized teaching and learning. Improved monitoring and accounting are matched by loss of privacy; improved methods for understanding the educational needs of the child may lead to further invasion of the sanctity of the individual. Yet these are not necessarily problems limited to technology. Any of the alternatives cited would be a product of improved capacity to achieve the worthy goals of improved public accounting or understanding the needs of the child. Frequently the decision is not whether to innovate. It is how can we achieve a desired goal with a minimal loss of an existing value.

Several of our panelists have urged the establishment of a center or a focus for the study of these and more specific policy questions on the use of educational technology. Such a center would also be devoted to the study of the desirability and feasibility of given programs and given systems to implement the programs. In addition to the broad social issues discussed and others relating to the impact of technology on values, style of thought and social organization (to be discussed below), such a center would organize required need and feasibility studies such as

a) Will given equipment be used?
b) To what effect?
c) How can we set up a tight loop of evaluation feedback and program improvement?

Dr. Carpenter describes the need for an adequate strategy of nationwide scope for establishing and maintaining balanced efforts for instructional program and equipment development. In order to do this, he suggests, the dimensions of the national need and the demand for programs must be ascertained and charted as a first step. A concept must be developed that considers software in the several media not just the computer. Whether the word software is inappropriate is not of concern. What is significant is that the programs interrelate and provide an educational milieu that is likely to achieve its objectives.

Such a center with the capability for conceptualizing, studying and problem solving, considering global and specific human and technological aspects of educational technology holds a high priority among the panelists. In this service, this study will highlight those questions and issues that have emerged as a result of its activity.

Predictions and Recommendations

The major part of this report is devoted to the development of critical issues in CAI and to possible futures in the use of the computer in education. Each participant has written in his own style and from his own contexual position. The discussion by the author-editors has endeavored to synthesize the product to a degree, and to enrich the report with other material derived from their research. However, it was believed that a summary of the recommendations and some of the predictions of the Seminar should be prepared as a separate section. It is hoped that from the several points of view made available in

a. the briefing
b. the consultant's chapters
c. the review of the seminar by the author-editors
d. this summary of predictions and recommendations

it will be possible for the reader to comprehend better the complexity and the dimensions of this field of endeavor.

The recommendations have been divided into two parts:

I. those designed to solve existing educational problems

II. developments that will further enrich or pose problems to educators. Some of these may arise from the introduction of the computer to education. These will include suggestions for advanced R & D and policy development. Several certainly will overlap. Others will appear cryptic. Reference to material in the text will provide great detail and clarity.

I. Recommendations relating to current problems of education:

A. Research and Development in the process of education

It was the opinion of the panel that the computer would, by providing increased and more dependable data on learning, accelerate educational research and thereby provide firmer foundations to our comprehension of the process of learning. By providing empirical, descriptive, and analytic information pertaining to administration or curricular systems, instructional materials, etc., it would improve this body of knowledge and improve the teacher's capacity for prescription and implementation. The increasing demand for individualization, both as a way of meeting occupational goals and of self-actualization will be furthered. The effects of individualization would also be determined and the optimal ratio of individual to group experience could be formulated. Study of individual and pluri-individual terminals could be undertaken.

Increased size in classes, particularly in secondary and higher education would be possible via the new technology applied to instruction, testing and scheduling. The effects on individuals and on the organization of education, as well as the optimal applications of such increases would be more readily available.

It is felt that there is a basic need to know more before we proceed too far. It is recommended that R & D into the process and dynamics of CAI and of education is a primary need at this time. That it should investigate problems of:

1. content
2. sequence
3. timing
4. configuration of input
5. optimal setting for education
6. organization of education
7. the effects of the various media of communication and then the relation to the several sensory modalities and learning.
8. teacher-student-computer relations.

It is suggested that this be approached from different, even divergent, points of view so that the fullest resolution of difference may be possible in a brief period of time.

It is urged that comprehensive systems of research and pilot programs be undertaken as soon as the necessary techniques are available so that we may determine the effects of the operating system as well as its elements.

B. Study of innovation via use of educational data processing.

It is anticipated that the greatest need and most ready application of the computer to education will be in data processing including such management techniques as:

1. budgeting
2. planning
3. inventory
4. scheduling
5. evaluation of progress
6. personal utilization.

Some will involve relatively simple bookkeeping, others will require complex and sophisticated model building.

The use of limited or ancillary instructional applications of computers such as dial access storage and retrieval or calculation will make our libraries and data banks more efficient. It will also further the application of the computer to the area of information handling where we may be losing ground because of the flood of new information.

Some use will not only satisfy serious current needs, it will facilitate the introduction of instructional (CAI) and other uses of the computer.

It is recommended that the non-instructional applications of the computer to meet existing needs be facilitated so that familiarity with the use of the instrument may develop while technological developments necessary to its instructional application is underway.

C. Social Change

The use of the computer for both administrative and instructional purposes will assist in the solution of many educational problems of the sixties and seventies. It is recommended that as policy is developed, full attention will be given to the extended responsibility of education for social leadership and the preparation of the people for more rewarding lives as well as needed roles in the economy and society. Such a task will require careful study and the consideration of more variables than we have heretofore been able to handle. The computer will play a significant role. Its nature will determine some of the characteristics of the study and new systam.

Among the immediate problems that should be considered in addition to the productive development of man are some of the dangers inherent in the increased knowledge about individuals necessary to such an advance. Full consideration and evaluation of the effects and implications of such a process should be undertaken from the point of view of the individual and society.

D. Coordination of the media

The rapid development of educational technology and the communications media has resulted in some considerable proliferation of non-compatible equipment, logic and systems. It is hoped that when the disadvantages of non-compatibility have begun to outweigh the advantages of divergent approaches, it will be possible to establish sound criteria and standards, and the educationally and economically advantageous goals of compatibility of equipment, languages, and systems. These should include instructional television, videorecorders, and the host of other technological advances, as well as the rapidly proliferating computer technology. The potential of the computer to coordinate these systems should also be studied.

E. Teacher Preparation

The needs for increased and improved teacher training are made more pressing by the demands for new populations to be educated and the increasing absolescence rate of existing training. It is urged that schools of education and other teacher training institutions and agencies be assisted to improve their familiarity with and investment in the use of the computer in education. This may be best accomplished through actual use of the computer in administrative and instructional modes. It will also be facilitated by the introduction of a systems approach to the study and practice of teacher education. Other relevant suggestions include the incorporation into teacher training of increased use of the inductive approach in the service of improved research skill by the teacher and her increased capacity for undertaking prescriptive activity directed to the individualization of education.

F. Counseling

The tremendous increase in the number and range of students coupled with the rapid surge in new information and technology heighten the need for improved and more efficient counseling. Education and the new technology are rising to the need, however, not without danger. It is recommended that the developing field of computer assisted counseling be supported. However, it is urged that careful attention be given to the danger of excessive dehumanization of the process. It is also of concern to the panel that we do not fall into the error of the self-fulfilling prophecy by predicting the potential development of individuals solely on the basis of previous experience that may not be a valid criterion in the face of changing circumstances.

It is also suggested that where possible such counseling systems employ the evident advantages of the computer by remaining current with the state of the employment market and the apparent future needs of the economy and society.

G. Systems approach

The challenge to education places great demands on the skills of educational administrators. New systems of instruction, teacher training, scheduling, accounting, and the sheer weight of the increase in numbers of students have created a demand for assistance to managers of the new educational agencies. We have also asked that they possess a level of knowledge and understanding of their schools that is unparalled. We have proclaimed that the effective unit in the educational process is the total system.

No understanding can be based on any one part of the system. The absence of systematic understanding would result in the serious danger of losing sight of critical elements that will affect either the acceptance of the innovation or the learning process itself. To make possible the achievement of these unprecedented demands on administrator and teacher, it is therefore urged that systems analysis involving broad application of the behavioral sciences as well as the hard sciences and education be accepted as a necessary prerequisite of major program development in CAI.

II. Future Developments:

A. Total Systems Approach

It is also recommended that the longrange development of education be approached from a "systems" point of view, that near term developments be incorporated in advanced thinking and that a point of view and a policy be developed that will consider the total learning environment as the proper province of education. Such a model would be based on an ecological approach to education and would consider as many stages, levels, and forces affecting learning as we are able to determine and deal with. Not the least of these is human development which is the basic phenomenon influenced by education.

It is recommended that exploration be undertaken of new teaching techniques and educational models built about the concepts and the capabilities of simulation, inquiry learning and other techniques presenting meaningful instruction to the learner.

It is also recommended that the objective of a flexible education be established as a result of which the individual will be capable of adopting both occupationally and psychologically to rapid changes in technology and society.

That such systems give the student an optimal degree of involvement in the programming of his own educational career so that it is responsive to his needs and goals and aptitudes within his knowledge of existing reality.

That research and development of such key and diverse elements of education as response analysis, analyses of the structure of subject areas and of the social forces affecting learning be pursued in the service of a fuller understanding of the entire system.

It is suggested that careful attention be devoted to the mental health and other psychological effects of change in educational methods. Such factors are often significant and unheeded parts of a system.

B. Social Impact

It is the belief of the panel that the use of the computer marks a quantum jump in man's technological development and more specifically in the enhancement of his intellectual capacity and his potential for knowledge of his environment and himself. It is the concern of the panel that these capacities be used for human welfare.

It is recommended that efforts be devoted to extend educational opportunity to new segments of the population that would benefit therefrom. The objective would be the establishment of the possibility for universal and lifelong education as required and desired by the individual.

The more effective integration of school with community and society should be sought. It is conceived as eventually possible that the educational system and the community will have the same goals, population, and even physical locus.

In this service, it is suggested that study be begun of the reorganization of the several academic disciplines, or at least their blending at some time in the learner's development so that education may more truly resemble life, and that problem solving in education may approximate the process in life.

That careful investigation be undertaken of the societal trends resulting from the introduction of the computer to education. Particular attention should be given to such critical areas as depersonalization and invasion of privacy which may be processes already affecting our mass culture. The effect of technology and technological models on human values and social structure merit attention.

That very effort be devoted to achieve the use of the computer as a tool rather than permit its emergence as a teacher or psychological model for the learner.

That a continuing dialogue on the relationship of education, technology, and human values be facilitated to determine and assess objectives, effects, and responsibility.

C. Hardware Development

It is anticipated that the development of new equipment will remain at least apace of the development of software and behavioral technology. However, there are areas in which the panel recommends particular attention. These include.

1. *Terminals and interfaces appropriate to the range of human perception and response and learning; i.e. multi-sensory techniques as well as pluri-individual terminals should be evaluated fully.*

2. Support should be provided for the *investigation of changing needs in the use of space in education.* The architectural and organizational character of the school and the distribution of educational equipment and personnel will be radically affected by new communications and computer technology.

3. *Research in biomedial contributions to information and education technology should be explored.*

4. *Efforts to improve the reliability of computers* and to provide accessibility to remote and unsophisticated users should be undertaken.

D. Cost Effectiveness

The development of cost-benefit systems for evaluation of computer use in education is inevitable both on a formal and an informal basis. It is recommended that suitable criteria, on a "macro" as well as a "micro" basis, be established and geared to individual as well as social gain.

That such assessments consider the full investment in the computer and its full benefit to education as well as the discrete learning and management aspects. Such separate consideration may unduly divide effects on the learner and on the system that are interactive and yield more than the sum of the two. An effort should be made to determine longrange and more subjective benefits as well.

That consideration be given to the many new methods and systems of communication that may lower cost and improve efficiency of computer applications to education. These include regional educational computer facilities, consolidated community systems, satellite microwave and laser transmission, increased off-line use, and time sharing.

E. Teacher Education.

It is recommended that we undertake advanced planning for the introduction of the use of the computer to the faculties of schools of education. Such a program will provide effective models for the education of their students, and facilitate the functioning of the individual instructor and the faculty as a whole. It should be based on a behavioral science approach to technology and its utilization, and should be related to instructional practice.

F. International Development

Longrange perspective and the realization that communications are shrinking the world should be accepted. It is recommended that planning for cooperation with other nations in the development of computer and technology aided educational systems should be implemented.

It should be realized that international instructional systems and international educational experiences for students will soon be possible. It is recommended that planning for the optimal use of such systems, and evaluation of their effect and benefit should be undertaken. Political as well as educational effects should be considered in view of our acceptance of the principle that no part of our system in unaffected by significant changes in other segments.

G. An Orderly Program of Development

It has been stated by a member of the panel that there is, currently, a lack of an overall plan for orderly, programatic and sequential research and development. Another member of the panel, reflecting the concensus, proposes an adequate strategy of nationwide scope for establishing and maintaining balanced efforts for instructional program development and for equipment development. The first step would be to ascertain the dimensions of national needs including the analysis of needs for programs and for new display media. This is intended to develop the perspectives upon which a range of instructional alternatives, equipment, and program instructional materials would be developed. Other related suggestions include that USOE initiate steps to achieve such a balanced and systematic plan with the objective of integrating government, industry, university foundations, and school systems to provide:

1. An adequate and appropriate supply of programs to meet the early experimental and pilot needs of CAI;

2. Development of support for R & D of new and original areas in computer use in education, as well as to facilitate the optimal use of existing areas;

3. Development of policy study methods leading to the optimal application of the computer to education.

At the last meeting of the consultants in New York, a further method for pursuing the development of CAI was discussed. It was the opinion of those present that a project should be devoted to the continuing appraisal of CAI systems. That it concern itself with a range of considerations from broad social implications to localized effects on state or local agencies or special population groups. It was suggested that CAI trends require conceptualization and study so that government, education, and industry, all concerned with the business of moving ahead, might remain fully aware of consequences and potential. Such an operation could relate to the Joint Commission on Data Processing of the Educational Laboratory Program and to other appropriate government or private organizations.

It would study the philosophy, approach, and implications of progress in such significant areas as computer languages, terminal design, program styles, personal use and methods for curriculum development that include the use of CAI. Such a project would remain current with the state of the art of CAI, its directions and its possible effects. Its basic function would be to alert those who bear the responsibility for decisions to necessary policy issues and alternatives.

Methodological addendum: It is recommended that such a mechanism provide constant attention to the effects of the Heisenberg principle (broadly conceived). This principle of physics seems to apply equally well to the behavioral sciences. Any effort to observe a process or, even more, to develop policy to deal with it appears to have a profound effect on the phenomenom itself even before the policy is operative.

APPENDIX

The three papers which follow were written by two young teachers and a behavioral scientist who assisted the project in the preparation of briefing materials for the Seminar. These materials were designed to introduce additional information from the point of view of teachers and a professional familiar with the problems of programming.

The staff paper by the Principal Investigator was prepared for the internal use of the Program of Policy Studies in Science and Technology. It is an expended version of the paper given at the Aerospace Education Foundation meeting of September 11, 1967, and an article prepared for the November 1967 issue of American Education.

The bibliography follows.

STAFF PAPER ON EDUCATIONAL TECHNOLOGY

Joseph B. Margolin

There is a revolution taking place in education, and it is not only the technological revolution - rather, it is the revolution which is built on the use of technology and the changes in managerial systems, as well as on research in education. The revolution is born of:

1) The introduction of a systems approach

2) The understanding that people may learn differently

3) The associated concern of the teacher for prescriptive activity for the individual child

4) In the very near future, it will likely include awareness of the total ecology of the educational situation.

Any consideration of the state of the CAI art must be presumed to be a consideration of the state of the art of education in which computer assisted instruction and educational technology are only special aspects of the system. There is no other art in the sense that art has to do with either a means of expression, or a means of conveying a message, or a means of achieving an objective. Computers, or even computer systems, are capable of delivering a good part of an educational environment; in that sense the computer is one of the media, or one of the instruments used in the art. To inquire of the state of the art, and mean machines, would be to inquire of Titian the state of the art and mean "what pigments are you mixing today?" Computers make possible many of the objectives that educators have had and will have with regard to the individualization of, monitoring of, and, rapid feedback from, the educational process. However, they are not education and they are not teachers. I am reminded of the enlightened engineer at the Pittsburgh Research and Development Center who responded to a question from my research associate about the use of a light pencil that, "It can be used for whatever educators need to use it for". The purpose of the art is to convey a favorable environment for learning. Anything else is a means to that end.

And yet even as the words are spoken they are clearly an oversimplification. The implications of this new technology must certainly be broader: for the teacher, for the educational administrator, for those who finance education, and for our economy. These additional objectives, as always, eventually achieve a kind of functional autonomy. The multiple objectives then become the environment in which the new educational method develops. It must pass more tests than were reckoned for when the task began ten or more years ago.

The new educational edifice that we are attempting to construct in a short time can become a tower of Babel. Conflicting philosophies and motivation, communication problems, differences in courage and capacity, all operate toward confusion.

The early stages of the development of any area should manifest divergencies of orientation, approach, pace of development, and goal areas. The evolution of any path requires that many be tried. Yet how will we avoid utter confusion and waste? How will we be sure (or less uncertain) that we have chosen the right vehicle instead of the Stanley Steamer? Can we anticipate and avoid the accident rate and the smog while yet embracing the most effective available means to our goal? The emerging policy, though not yet fully formed, will determine the economic and human cost and effectiveness of this new tool.

The U. S. Office of Education Bureau of Research is supporting several studies and programs that seek to minimize errors and miss-steps and foresee a bit of the future. One of these, "Education in the Seventies," dubbed "the flying seminar" by Dr. Ray Carpenter, undertook a unique avenue to study the future of computer assisted instruction as a project of the Program of Policy studies in Science and Technology.

Twelve senior scientists and educators were assembled in a balanced team. The members included the president of a university, two deans of education, a sociologist, an architect, two psychologists, two educators, a director of curriculum development, a psychiatrist, and an economist. Considered from another viewpoint, they reflected competence in engineering, educational research, research and development (R & D) in educational media, school design, program development and innovation, systems analysis, programmed instruction, etc., etc. The permutations of resources and the perspectives of the group seemed endless.

After three days of intensive briefing by educators, government and industry, the group set out on a weeklong aerial trek to the four corners of the world of American education. Their itinerary was balanced and programmed to present the developmental phases of CAI, the different problems being pursued, and the varying and often divergent approached to them. A variety of R & D institutions were visited, two universities, a "non-profit" and two profits, as well as a fully individualized elementary school, and two "just plain" elementary schools with electronically programmed systems of education. All the centers visited had two things in common: they are advanced centers for R & D in CAI that work with real children in real schools, and each is unique.

Throughout the nine days of our safari across America, discussion never ceased. In hotel lobbies, late into the evening in a member's room, in restaurants or in airplanes and autos the interaction of this heterogeneous mixture of scientist-citizens continued to elicit new issues, solve problems, erect hypothetical structures only to tear them down, and explore the world in which they travelled and the style in which they thought.

When it was over, each returned to his privacy to list the issues he perceived and to present his map of the road into the future.

From our explorations we emerged with something of a view of the "state of the art" in CAI. However, such a view, full though it is with promise and future, contains more issues and questions than it does facts. The "facts" change almost too quickly for reporting.

Unfortunately, the "state of the art" usually conjures up a picture of flashing lights, cathode ray tubes (CRT's) and children with Buck Rogers earphones and ultramodern light pencils seated in little cubicles. Again, we cannot consider "the art" to be limited to technology. It is educational technology, the art of teaching or helping students to learn. Awesome as the technology of the computer may be, it is simple compared to the complexity of the real subject of our discussion: the changing state of the art of education as it is currently affected by the vast opportunities and dangers of a major technological leap forward, and is motivated and pushed by the tremendous social and economic pressures on the system of education today.

After the initial embracing of the computer and CAI as the new deity, the next step has been to back off and worry about the dangers of automatum.

Some perspective is needed. The computer is a basic advance. It is in a class with the wheel and the printing press. The one contracted space, the second expanded knowledge, and the computer may be our true "consciousness expanding" instrument for it relieves man of weighty memory, tedious chores, and energy-consuming vigilance. It permits him to think freely and to have at his fingers a tool that can automatically do a wide range of complex tasks on command - wonderful, yet still a tool. This we must accept lest we give it too much credit and ourselves too little responsibility.

These were the lessons learned at each site we visited - that education is a complex system in which the computer and other technology are only facilitators - that the computer and its terminals are tools of the teachers and the student! They are tools that permit systematic approach to individualized instruction - a path to what we estimate will be a critical improvement in the environment for learning.

The best school would seem indeed to be "a teacher and a student at opposite ends of a log." Unfortunately we do not have enough teachers or dollars. CAI offers a way out, a way fraught with both pitfalls and promise. It can provide a rich and varying input and response, sound and systematic instructional bookkeeping, new insights into the process of learning, and above all, individual and flexible education.

How does this new technique look to the educational administrator? What does it offer him by way of tools? A brief overview of the teaching logic of CAI is necessary if we are to anticipate problems.

Babel -- Mother of Inventiveness and Confusion

We are still in the early stages of research and development in CAI. The researchers still constitute a small club; conferences and study sections change their locations, but usually contain the same cadre of individuals. As one might expect at such a stage of development each man and each organization is following its own objective and its own philosophy.

Some of the systems that have evolved seek relatively simple interaction with the learner. They offer simple problems, relatively few alternative answers, and result in a "tight loop" of reinforcement designed to improve the student's performance according to predetermined criteria. They move up and down the scale of difficulty according to the learner's success. These are generally described as "drill and practice" exercises. Their value lies not only in the experience gained by the learner, but in "relative" ease of development. More advanced systems of this type will be able to increase their repertoire by learning new "correct answers" from the learner.

More complex systems engage in more branching and direction of the student to the proper level and quality of work indicated by his performance. Eventually we may "hand tailor" the sequence to the student's cognitive style. This category of instructional logic is described as tutorial. Tutorial systems range from linear, in which all students negotiate the same path, to the adaptive in which the question presented depends on a series of prior behavior by the student and/or instructor.

A more sophisticated level of CAI at this time is the "Socratic dialogue" exemplified by the medical diagnosis program prepared by Feurzeig. In this logic the student can ask for information and introduce a response at any time. It may simulate a time dependent process or a game and has the basic characteristic of interaction between learner and program.

Other educators have stressed the simulation or laboratory method. It is closely related to the Socratic methods in following an inquiry logic. Of all methods the potential of this is greatest for providing learning through interaction with a complex environment. Effective simulations of economic and political systems suggest even more realistic dramatizations of the learning process in the future.

In some gaming procedures there can be more than one learner (or player). The computer acts as umpire, calculator, and data blank.

These logics and others are closely related to both the computer language and the hardware used. In view of the high goals and the creativity of those in this research area, it is easy to see why there has been so great a proliferation of languages, hardware systems, and philosophies. It would require several volumes of this journal merely to describe the languages currently in use.

The implications of the "Babel" that we have created are less easy to understand or resolve. Most certainly, we need more divergent thinking and creativity, a wide and flexible armamentarium. However, it is also true that there is a unique market for this product. There are in this country 20,000 autonomous school districts, many of which pride themselves on providing freedom to individual schools. Within the schools there are differences in teacher style and student need that may lead to alternate prescriptions. If we are to leave some creativity to the teacher, principal, and curriculum development staff we must establish some compatability of hardware and software and bases of communication so that the educator on the line may assemble his own system, or communicate with others. This goal constitutes another of the complicating aspects of the development of educational technology. Harold Borko, in a review of computer applications, sounded the same alarm:

> "We have seen many advances in the design of computer hardware. Not the least of these is the proliferation of new computers that are appearing on the market at an increasing rate. This fact is of great significance to the programer. One can study, work hard, and become an expert programer on one machine. Then, for any one of a number of reasons (the programer takes a job with another company having a different machine, or his own company changes machines, etc.), he is no longer an expert. True, there is some transfer of training, but the programer must start again to learn new codes and a new machine language. Were only a single individual to find himself in this situation, it would be merely sad; but since this has been the common experience of many programers, the waste in man power and money is tragic." 1.

Languages, such as Planit and Coursewriter have been developed. These permit the teacher to take the basic principles and format of a program and with a minimum of instruction modify the course to suit his desires. Yet even with Planit and Coursewriter and their relatives the task is expensive and the paths of the several developers diverging. Currently we offer to our schools only two alternatives: 1) very expensive programming; 2) the purchase of "packaged" systems. A third choice would permit the assembly of unique systems using compatible components.

An even more exciting but remote development will be the use of natural language in conversing with the computer. It may seem that this is taking place in some of our Socratic programs. In such cases, the

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1. Borko, H. "A Look Into the Future." COMPUTER APPLICATIONS IN THE BEHAVIORAL SCIENCES. (Edited by H. Borko.) Englewood Cliffs, N.J.: Prentice-Hall, 1962 p. 601.

computer has been programmed for a wide range of contingencies. It will require 1) the solution to the problems of pattern recognition (well along), and 2) the capacity for drawing inferences and simulation of cognitive processes and language behavior. When these have been achieved, computer comprehension and response to natural language will be possible.

The problem is even more formidable when we realise that CAI is only a small corner of educational technology; videorecorders and players, language labs, etc., are all part of the armament of a modern school. We may hope that the computer will ultimately assist the teacher to coordinate and monitor this vast assembly of hardware. Yet how is this feasible in the face of the assortment of conflicting frequencies, logics, and languages? Either we must achieve some level of compatibility or an efficient system of translation.

CAI and Research in Learning and Teaching

The advent of CAI and the broad use of the computer in education open new vistas in educational research and development. Most of these could be accomplished now if the equipment and the school system using it were available. Others are an effort away.

Most current educational research has been based on impressionistic or vague data from "real-life" situations or less than generalizable products of a laboratory situation. The danger of tomorrow is that of a data overload. Too much "hard data" may be available. Each response of the student in an automated system will be monitored and recorded. Content and process, timing and configuration of response will be available to the researcher in degrees of fineness previously unavailable and even less manipulatable. It will be a challenge to the researcher to develop theory and method that control and make use of the flood of "available data" - and available it is without subjecting students to tests, lab conditions, or other nuisance work.

The great promise is the availability of the total learning situation. The task of the researcher will be to analyze and conceptualize the several aspects of the entire event and to put it together in a working whole, encompassing content, instructional or teaching variables, and learner variables. We can conceive of great strides in the understanding of the character of specific subject matter in areas of knowledge, and on the learner side of psychological, perceptual, cognitive and other factors that distinguish one student from another, and modify his approach to the many content and educational process variables.

There are many gaps in our web of evidence and more than a few in the base we build for further progress. For example, many claims have been made for the systematic and scientific quality of programmed instruction. That it is systematic is undoubtedly true. That it is scientific or valid is supported only deductively from Skinner's experimental work with pigeons and some of the other experiments with animals. Programmed instruction is based on the assumption that the subject matter is best presented in small bits to the student who actively produces an answer to some response. The student must be allowed to proceed at his own pace at his own level. The application is sensible, it is very likely valid; however there may not have been sufficient experimental support for these assumptions, even less for the system that binds them, and almost no study of the gestalt or configuration of the small units of information and questions presented to the student. These, in Hilgard's view, may be more critical than the size of the unit or its content; thus more research is needed into the process and the configuration of the program.

Much emphasis has probably been placed on the size of the units in the system. This is excellent if the entire learning situation is considered part of the system. However, too often it has been the program, the teacher, and the hardware without awareness of the characteristics of the subject and other environmental factors. Licklider, for example, found that poor typists learn more rapidly when they respond implicitly, that is, when they just pushed a button telling the computer to go on that when they responded explicitly, when they typed the response. While good typists show no difference in learning rate between implicit and explicit response, obviously there are more barriers to the achievement of some closure for the poor typists than there are for the good typist. Perhaps the gestalt model is helpful and should be introduced into whatever theoretical system is established. Certainly we are learning that it is difficult to alter part of the system without thereby altering the whole.

It would indeed be unfortunate if the type of "jurisdictional" or theoretical squabbles that have accompanied the development of experimental psychology were to become characteristic of research in the new educational process. It would also be unfortunate if the aura of experimental psychology, whether it be learning theory, or associationism, or gestalt psychology were to be so powerful that all of the scientific effort followed a single approach.

Basically the need would seem to be for more new formulations and the development of an adequate theory of learning making the fullest use of the gains of classical theory. There has been little inductive work in education. Qualitative departures from the hypothetical-deductive approach are found at Stanford in the procedures which operate from specific learning situations toward the development of quantitative learning models, and at such places as the University of Illinois and in Cambridge at Bolt, Beranek, and Newman, Inc. where a Socratic method leads of its nature to the development of the configuration necessary for learning.

In technique as well as in theory, we need more research and understanding. All too often the concepts of student self pacing and student self determination are observed in the breach. As Coulson discovered when studying the relationship of branching and fixed sequence systems, student self evaluation is a considerable aid in determining what kinds of branching should be undertaken, thereby fulfilling the self pacing and self directing concept more satisfactorily. Self pacing is also affected or minimized by the slow time involved in the typewriter printout of a question or an item. Cathode ray television screen presentation of the question directly and immediately may hasten the presentation. By the same token, it may interfere with the control of the student's reading process which takes place when the typewriter forces the student to read straight ahead instead of by the very destructive flashbacks that are the patterns of poor readers. Thus something may be going on in the presentation via the teletypewriter medium that is beneficial without its having been the intent of the programmer or the teacher. Only the isolation of such problems and their solution will suffice.

Big Systems vs. Little Systems - Is Size a Threat?

There are some questions that straddle hardware economics and social and humanitarian issues. The controversy rages and will for some time over the relative advantages of independent "free standing" systems immediately subject to the control of the teacher or principal, and the huge computer with its cental data bank and terminals through the length of the system.

There is much to be said for each. Economically, absence of expensive transmission line changes, flexibility, greater reliability, local control, etc., would seem to favor the separate unit.

Central storage and extensive time-sharing, lower costs for technical personnel and programs would seem to favor the giant unit.

Perhaps the two approaches are not mutually exclusive. Central high speed and capacity computers can operate in concert with local systems as satellites. The dual advantages of centralization of data and local flexibility can be achieved. Indeed, in many communities we may look forward to a time when in a city or county, health welfare and educational records can be joined with demographic and census information to the advantage of student and family and community.

This immediately conjures up the dark genie of invasion of privacy. And a problem it is. Yet there are those who would eliminate the automobile to avoid fumes and accidents, or the telephone to avoid wire tapping. This kind of clock turning seldom works. Rather, it would seem to be the responsibility of the administrators of such programs to develop systems that protect the individual while according him the advantages of the technology. It is also possible that hand processing of such data offers a greater threat to privacy than electronic storage. It may be only that we have become accustomed to those dangers and abuses. Thus we fail to see the problem of big systems versus little systems. The task is how to achieve the advantages we seek and minimize the dangers we fear.

How Will the Computer Come to School?

The staff of the Educational Policy Project talked with several school superintendents and others concerned with innovation in education. Despite the introduction of CAI systems in a few pilot settings, the major use of the computer in education is in the management and fiscal areas. Here administrators can draw on years of experience in business and banking, and adapt them to the unique needs of education. Payrolls, budgets, schedules, and inventories benefit from electronic bookkeeping. Increasingly, school records are moving towards such a system of rapid storage and retrieval. Scheduling, budgeting, and even dial access libraries are well along. When CAI comes to the schools, it will find its "cousins and its aunts" nicely ensconced. The advantages are great. School personnel will be familiar with and masters of "the monster". In many places, the capacity for application to instruction may exist, and the outlines of a school-wide system will have been prepared. In some of these schools, computer printed report cards are accepted along with the anecdotes about students who failed recess. It is better to work out the bugs on such difficulties than to disturb a class with "down time."

Thus, if we plan properly, the hardware will be ready and waiting, and the familiarity with the value and problems of computers well established when we have overcome the programming challenge. The computer may even offer the solution to the scheduling and monitoring of the flood of uncoordinated educational media that has hit the campus. As a record keeper, it can help in the vast job of evaluating the effect and organizing the application of these useful, but problem laden servants. It provides a continuing assessment of the learner's progress. As he progresses, both input and achievement are recorded. For the teacher and the administrator, it will be an efficient scribe taking note of the components and gestalt of the educational environment provided for the child, as well as their effectiveness. As we have noted above, for the researcher seeking to enrich educational theory it will be a treasure trove of hard and appropriate data encompassing the content, the process, the configuration, and the ecology of learning.

With the aid of the computer itself a system of CAI can include the entire school environment making use of the architecture and the organization of the school and educational systems as further tools of the educational planner. All of these factors have long been in the mind of the educator. Never before has he had the tools with which to study and apply this multitude of variables.

The gestalt of the educational environment suggests an interesting concept. Perhaps we can create a new kind of "book" for each child; one that takes note of and is geared to his perceptual and cognitive style, that addresses itself to his areas of interest and enthusiasm, to his pace and his level of maturity, a "book" that can draw on wide resourses of data, computation, or laboratory from the Library of Congress or the AEC laboratory to an active simulation of the Battle of Hastings or the mercantile system. Such a "book" would exist in the memory of the computer, on his CRT, and where appropriate, it could be reproduced by xerography to be taken home for study. Above all, it would be his - the only book of its kind in the world.

These but a few of the promises such a system offers to the educator. It offers him a powerful tool, control of the whole system of education. Further, if he can utilize the computer as an educational vehicle, he will be seen by the learner as the master of the new industrial and intellectual revolution. The example of the teacher is the crowning educational device. It is often the most important thing acquired by the student.

What of the effect on the teacher? The vision of rows of computer terminals displacing the teacher can only be folly when we observe the effect of modern technology in a society that is closer to full employment than we have ever been. However, CAI will produce changes. Rote drill and practice need no longer be applied by the teacher. Test scoring and record keeping, those after hours tyrants in the teacher's life will be obediently performed by the CAI system. Access to films, exhibits, and laboratories can be available at the touch of a button.

The principal change will be that in the role of the teacher. The nagging concern of the conscientious instructor about the individual attention needed by the slow or the advanced student can be relieved. Armed with more time and more information about the student than he has ever had, he can shift from medicine dispenser to physician, observing the characteristics of the individual and prescribing for his needs. Even without a computer, individualized instruction is being used at the Oakleaf School in Pittsburgh. Few visitors fail to be impressed by the benefits of the prescriptive role to both student and staff.

How will this revolution in teaching come about? Can we have a magic light pencil and transform our teachers? Certainly not, yet the relative ease with which a few teachers have adapted to CAI-like systems in Palo Alto, Pittsburgh, and Brooklyn suggest that the problem is no insuperable.

In-service training using the computer is one possible avenue of retraining. Even more basic is the need for the introduction of CAI, dial access, and calculation facilities into our schools of education. It would indeed seem strange, if the last men to have flight experience were to be our airline pilots. Little success has been achieved in denting the graduate departments of education. These should be the first objects of a combined government-industrial effort to introduce CAI on a large, well funded basis.

Through recognition that these are new and talented tools that will elevate the teacher's effectiveness and his status in society, the change can be wrought. Only in this way can the teacher become familiar with his new tools, learn to master them and his latent fear of them, and provide a good example to his students.

Is Innovation a Problem for Students?

We can already detect the allure of the new equipment in the number of "computer clubs" organized in our schools. Many of the items discussed are essentially overhead to the student. He sees no more of them than we know of the contribution of the taxes paid by the Green Giant Corporation to the cost of a can of peas. The student, depending on his age and maturity, may comprehend the whole system or none of it. What he encounters is a terminal, the so called "interface".

The terminal may provide only an electric typewriter with teletype connections, or it may be a multi-sensory device providing sound, words and pictures (sometimes in color) on a screen or tape, even providing the feel of response via the typewriter key or the application of finger or light pencil to a surface.

These are the mechanical characteristics of the interface. Depending on the system and the program, he is presented with background material or a lecture, and asked a question. He receives a prompt comment on his response or inquiry ranging from "wrong, do it again" to a highly sophisticated prompting or guidance to the answer. He may be involved in the solution of a problem, or play a game, or be engaged in a simulation. These are a few of the instructional processes. There are other resources and other formats. He may be guided through the course by the computer or the teacher, or the student may assume responsibility for decisions at many points. He may have a library and a powerful calculator at his disposal, or neither.

The material can be provided via television, videotape, slides, sound tape, or even the direct voice of the teacher or booth attendant, as required. His mode of response will be via typewriter, pencil, light pencil, voice, or the written word. Ultimately the three dimensional hologram may present an infinity more complex stimulus to the student.

Out of the infinite permutations and combinations of modalities and media we can develop the interaction of student, teacher and computer. The advantages to the student are evident. Continuing involvement in school work at a level and pace that is tailored to his own learning is enough to subtract boredom from education and promote the kind of self-actualization that psychologists prescribe. Rather than foster conformity, it would seem that CAI can enhance the subtle differences between students that are so often smothered by the uniform chant of the linear educational model.

Undergraduate, graduate, and pre-service training may be affected quite soon. Basic courses in psychology, statistics, German, and logic are already available via the computer. The "dry lab" may never replace the smell of hydrogen sulfide or the badge of the acid burned lab coat, but it will offer valuable pre-laboratory experience at a cost far less in time and equipment and space. Through simulation the laboratory concept will most certainly be extended to the social and behavioral sciences, and even to history and literature.

The individualization of education at this level will make possible the seeming paradox of high academic and professional standards and idiosyncratic career lines geared to the personality, the goals, and the capacity of the individual. Mass production in education may be a thing of the past. The initiative of teacher and student may operate to hand tailor the education of each child from his earliest years. Several factors suggest that the computer may operate to personalize rather than to depersonalize education: a) the large quantity of information about the individual that the computer can store and use; b) the increased freedom of the teacher to consider his students and to prescribe; c) the potential of the computer for individualizing materials.

The Computer and the Economy

We have considered the advent of CAI as an 80 billion dollar industry. In the education industry it will produce a better trained, more effective practioner equipped with powerful new tools of his trade. The product of the education industry should be, if we do our jobs well, more flexible, more the master of his occupational fate, and better equipped for his role in society. However, its impact on education is only a part of its total effect.

First examination suggests the end of occupational unemployment and even of skill absolescence. Computer terminals readily at hand can keep the engineer, scientist, physician, teacher, even the housewife who has left the labor market and plans to return, fully abreast of the rapid pace of technological change. The disappearance of demand for one skill will be followed by a period of rapid transfer to another. On a more global level education could become the major consumer of the national productivity, a stand-by industry when defense will no longer consume so large a chare of our resources.

The State of the Art and the State of the Job Market

Very basic changes are occurring in the employment market. The computer, numerical coding (N.C.) production, and automated heavy labor are rapidly making unskilled labor obsolete. They are producing an even greater change in the skilled and semi-skilled areas. Such industries as printing are moving in a scant few years from hand type and linotype to electronic type setting and plate making, or even more direct printing by computer.

There is a great need for familiarity with the computer and electronics and an even greater need for computer assisted vocational and on-the-job training. If we can introduce the computer into vocational and professional education, we will have dealt with both problems. Automation in vocational education and on-the-job training are developing rapidly despite the resistance of some of the orthodox trades.

The Bureau of Research of the Office of Education is developing an "organic curriculum" designed to invest much greater flexibility and responsiveness into vocational education while simultaneously enlarging the personal scope and character of the learner.

A very significant improvement in "occupational fit" and in job training may develop from recent work in student counseling. It is now possible to monitor, absorb, and process sizeable amounts of information about a student's interests, capabilities, and achievement and to relate these to the evolution of his occupational choice. The student may be able to maintain a continuing dialogue with both counselor and a computer-based counseling system wherein he is constantly adapting and refining his choice. It is possible to integrate into such a system the critical variables of student interest, capacity, experience, and the current or projected state of the educational and occupational market. The training lag may be maintained in this way, and eliminated by effective use of continuing education.

The space program and Department of Defense training methods have also given us much experience in intensive systematized vocational and even professional education. DOD's project Transition will undertake the further generalization of this training to civilian skills and occupations.

Higher education and professional pre-service and continuing education offer particularly high potential for CAI. Rapid changes in almost every profession and scientific area require either frequent refreshers or continual reading of journals. Data blanks and dial access libraries are completely within our capacity, and are in growing use. Soon we may expect engineers and architects to refer to a rapid scanning and access service for information on materials stress, capacity, availability, cost, etc.

Will the physician, psychologist, or engineer be able to afford the terminal and line changes? They may be high at first, but the tendency of professionals to work in close relationship to each other in medical buildings, hospitals, laboratories, etc., will make sharing of terminals common at first. One may hypothesize that new professional buildings will soon offer computer rooms or computer jacks for dial access information or "calc mode" service.

Yet CAI is not all "gravy". Problems abound. This could also become the age of the dilettante. 1) We might well be faced by too rapid movement of individuals to satisfying or remunerative occupations. 2) There is a potential lack of fit between some elements of the new individualized education and the demands of society. Emphasis on individual problem solving may ill prepare a person for life in the highly organized and group oriented society of today and tomorrow. 3) Individualized instruction may also be an incomplete concept. It perhaps should also be described as "self paced" and "self initiated" for without respect for the considerations of incentive and motivation we have lost sight of the problems of the deviant child and the different cultural groups.

If education is to join with urban renewal and other renewal and other elements of our society in healing some of our major social ills, it will have to attend to the special cultural problems and to the ecology of the learner's life in the process of teaching the whole person. Indeed, improvement of our understanding of the ecology of learning is a more general need. Research in perception, cognition, and learning and the new developments in computer assisted counseling may provide two of the contributions to a science of education that is no longer divorced from its ends, its means, and its philosophy.

It is probably not necessary to comment on the potential for continuing education and in-service training in industry. The value of rapid availability of training materials to supplement the skills of workers while they are actively engaged in a project should be considered. We could be able to provide rapid and on-site training ranging from tool skills to trigonometry to an explanation of the dynamics of a new drug for learning that cannot be matched. Neither should we underestimate the great increase in the flexibility of the human that is offered.

There is an even more potent gain to the individual and potentially to society. Such a system could provide the confidence that "not knowing" is not a sin, that it will not result in loss of job or status as long as the effort is made to meet the need. Such an employee or professional is no longer threatened by admitting his weaknesses for by doing so he can be strengthened. This basic change in the relationship of job skill to employee can provide unprecedented stability to the individual and to industry. Its contribution to social-personal-mental health seems evident.

CAI Futures.

The state of software and programming will affect the development of CAI today and tomorrow. The process of programming awaits the breakthrough that will make it less time consuming and less expensive. We have also discussed the need for compatibility of languages which will likely multiply the effect of those now working separately.

The lag in the development of good programs in a wide range of subjects also derives from the football of financing that has been tossed back and forth between government, industry, and education. A sound consideration of policy governing R & D costs, copyright and franchise rights will go far to open this bottleneck. Such a policy study would do well to consider, as a context for the legal and economic decisions, the far-reaching changes that will be effected by computer technology. The computer will have produced a new environment that should be the basis for current decisions.

In the corporate world, the impact of the computer and CAI on the education-relevant industries has already been felt. Electronics and publishing companies merge like sodium and chlorine ions in a drying salt solution. Printing is rapidly being automated, and computer type setting may endure just long enough to be superceded by direct electrostatic printing. In short, a change in the content and the structure of the publishing, communications, and education industries will produce many policy problems. Rapid obsolesence, new products, new distribution modes, and increased demand by the public are but a few of the challenges. Rapid retraining of personnel, careful planning of production and inventories by industry, and realistic recognition by government of the costs of development and rapid obsolescence may get us past a crisis born primarily of the acceleration of our pace of development. Perhaps most critical is the human decision of the individual to change his view of himself from the static identification with one trade or skill to a more meaningful respect for his own flexibility and mastery of any challenge. The communication of this concept is the responsibility of education.

The problem is economic and social, and it hereby becomes political. The development of sound policies that take cognizance of the few considerations mentioned and the host unspoken will be necessary if we are not to stumble and slide into the third industrial revolution.

The information in this paper demonstrates enthusiasm at top administrative levels for the use of computers in schools. This appears to be contrasted with the uneven reception by teachers. The conclusions provide one picture of the context into which CAI is being introduced. They point to opportunities and problems, and at the very least indicate that there are limits to the capacity of any administration to impose a system which requires the active involvement and enthusiasm of people on other levels in the system.

EDUCATIONAL ADMINISTRATION AND COMPUTER SYSTEMS

Phyllis McDonald

Introduction

Industry has achieved a level of expansion and efficiency inconceivable prior to the advent of computer technology. Aspects of business and production adaptable to computer technology are rapidly being automated.

Pressures of increased population have catapulted education into expansion also. Urbanization, added to population expansion, has forced merger of many previously autonomous school jurisdictions. The current size of student populations ranges from 500 to 100,000. Record keeping alone for 100,000 students requires automation. Yet in 1961, only 5% of all computers in use in the world were in educational systems, and there is little evidence that the relative situation has improved.

While educational data processing offers a tremendous aide to the operation of school systems, it is Computer Assisted Instruction of the two that is receiving the glamour rating in education.

Both industry and the Armed Forces have embraced the use of CAI and other technological aides when a given instructional process needs to be communicated to large numbers of individuals within a short span of time. Nonetheless, elementary and secondary education appear reluctant to utilize the new technology.

This paper is an attempt to explore the potential uses and problems for the school administrator that are inherent in educational data processing and Computer Assisted Instruction.

Part I: Educational Data Processing

A. School districts in the U. S. are organized in varying jurisdictional patterns. These range from small, autonomous, single schools to comprehensive county systems responsible for up to 100,000 students. The utilization of computers has been almost as varying as the nature of the many school districts. Some have moved ahead with dispatch, others have not yet considered the possibility.

The city of Milwaukee computerized its elementary and secondary school administrative data processing in 1966. The Director of Data Processing jubilantly announced at the end of the first year a saving of $400,000. A portion of this figure is attributed to one week of teaching time saved as a result of freeing teachers from clerical duties. The city was able to schedule classes for the 26,971 students in all senior high schools in less than five hours of computer time. Normally, the same task has required a minimum of 20 working days per school.

The computer is housed in a central administrative headquarters. Centralized data processing is applied primarily to data essential for daily local school administration, such as class scheduling or attendance. Rapid feedback of data is available to individual schools since each maintains control over its own data.

An example of similar success on a smaller scale is the South Colonie School District, Colonie, Albany County, New York. (Junior high school population - 500 students; total District employees - 700) The emphasis in the South Colonie School District is on storage of cumulative data, scheduling, and homogeneous grouping in a pattern of feeding several smaller schools into a single, higher-level plant. Some experimentation with research data has been attempted. Future enrollment and residential patterns have been predicted with increasing accuracy.

Contrasted with the Milwaukee schools, the Colonie District is small. Total control of the computer can be exercised more conveniently by the central administrative office. A large proportion of the data accumulated is used to facilitate overall planning and operation of the school District. One significant illustration is the computation of payroll figures for 700 employees in 16 minutes. Another is the use of the computer to group students entering a junior high school from seven elementary schools on the basis of academic achievement. It is not clear whether differences in application in Milwaukee and Colonie reside in the computer systems, or in the simplicity of communication within the smaller school district.

Montgomery County Maryland is a third jurisdiction which has experienced success with educational data process. (Student population - 100,000) Computers installed in 1962 are housed and operated by the Department of Finance located in the school district central office. Their primary use is daily data processing.

This past year, interest has developed in the research potential of the massive records now stored in the computer's memory bank. A test grading service has been initiated for the teachers which is gaining in popularity. Teachers can receive back teacher-prepared objective tests, scored and graded, within 24 hours.

Developmental features characteristic of these jurisdictional patterns are evident:

1. A major portion of the computer workload involves clerical data processing as opposed to research.
2. Daily record keeping such as of attendance, grades, and cumulative record data for individual students is submitted by all schools and fed back as needed. Attendance, for example, may be submitted daily, then retrieved at the end of the educational year by each school.
3. Individual schools do not have need for, or access to, data from a second school.* See Diagram A.

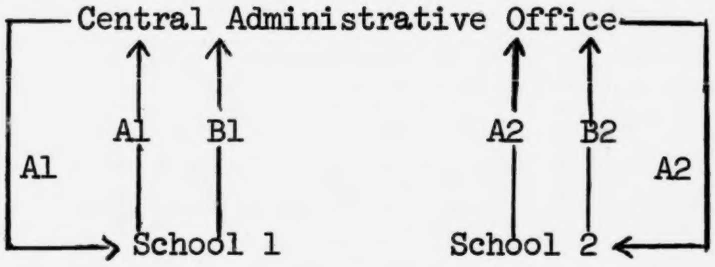

Diagram A: Two types of data may be submitted: A-type, or clerical; B-type, or research. A-type can be returned while B-type is kept; or both may be processed for a given purpose and emerge as a third type for central office, or other use.

4. There is enthusiasm at the central administrative level for data processing by computers as a direct consequence of their efficiency. District offices view the system as highly successful: the computer fulfills its assigned task, that of relieving administrators of the problems of daily record keeping. However, other levels in the system, such as teachers and auxiliary personnel, also benefit from automation.

B. A second developmental pattern has arisen in education as a direct result of the advent of computer technology. This second trend consists of the organization of educational units on a magnitude previously unimagined.

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*The Milwaukee school operates on the premise that the success of computerized EDP is contigent upon each school maintaining control over its data. Each school in that system has an official who serves as coordinator and programmer of EDP. In most schools, the position is held by the Assistant Principal.

1. Project Update in the State of Iowa is a prime example of a major innovation in education, unique in organization and implementation.

Research is the primary goal of Project Update. Each public school in Iowa feeds its data into a central computer center located at the University of Iowa, Iowa City. Dr. Lindquist of the University of Iowa designed and developed the system for educational research.

The amazing rapidity with which the system was organized and installed on a state-wide scale is initially awe-inspiring. The University of Iowa, a state school, works closely withe the Iowa State Department of Instruction. The contribution to education derived from the state-wide system has become evident. Gains could be made in several areas:

a) comparative research projects;
b) state funding follow-up;
c) teacher certification;
d) analysis of current educational environments of varying economic areas within the state;
e) future effects of state policy decisions;
f) ultimately the establishment of meaningful and realistic teacher-performance criteria throughout the state.

Implementation of the system was not free of problems. Orientation of 2000 school staff was undertaken by written communication. The first instruction booklet submitted to local administrators consisted of some 56 pages. (Future publications, realistically, will be shorter as the local administrators become acclimated to programming procedures.) Individual supporters of the use of computers within local schools had to be depended upon to overcome resistance of colleagues to the new system.

Currently the State of Iowa is participating in the program of Regional Educational Laboratories. The small computerized systems are more useful to local school administrators for several reasons. Since each unit within the Regional Laboratory services fewer schools, problems which arise in individual schools can be attended to more effectively. Data of a more practical nature can be processed for individual schools with freer flow of input and, more significantly, of retrieval. At the same time, the State Central Laboratory has access to selected data needed for research and state administrative use.

2. The Southwest Regional Laboratories for Educational Research

is an organizational giant in education. The System Development Corporation is actively involved in this program. A central facility will serve the states of Arizona, Southern California, and Southern Nevada. Elementary and secondary units, colleges, universities, and industrial resources will cooperate for three major purposes:

1. In the area of instructional management, teachers will be provided information on individual pupil progress.
2. In administrative planning, high-speed retrieval and summary of personnel and fiscal information will be made available.
3. Wide-scale curriculum evaluation will be attempted.

The S. W. R. L. will be administered by a Board of Directors comprised of representatives from: the State Boards of Education of the three participating states; the Regents of the state universities; the trustees of California State colleges; the superintendents of public school districts in each state.

Similarities can be noted between Project Update and S. W. R. L. in addition to the obvious ones.

1. The implementation of both projects was made possible through intervention of a higher central authority. In the case of Project Update, the State of Iowa required each local school district to participate. The Federal Government (U.S.O.E.) provided the necessary funds for S. W. R. L.

2. The success of both projects is contingent upon the cooperation of educational jurisdictional levels which in the past have remained nearly autonomous. Merging of large scale educational research interests is now possible with the advent of computers and federal funding to education.

These two salient features of Project Update and S. W. R. L. have given rise to concerns which permeate all educational administrative levels.

The fears and negative speculation engaged in by education administrators may not be valid but they are real at the present time.

Topics discussed at the various regional conferences of school administrators, Spring 1967, exemplify the existing attitudes and concerns of local administrators. The following list includes titles of papers presented at this conferences:

SOUTH ATLANTIC CONFERENCE

1. Emerging Forces in Reshaping Education
2. The New Teacher

3. What Are We Administrators Going to Do About the Future Role of the U. S. Office of Education?

SOUTHWEST CONFERENCE

1. The Shape of Things to Come
2. The Regional Educational Labs
3. The Role of the School Superintendent in Negotiations and in His Professional Associations at Local, State, and National Levels

NORTHERN NEW ENGLAND CONFERENCE

1. Challenge to Educational Leadership
2. What are the Major Regional Research Thrusts in New England?
3. Hardware - Software Merger: Scope and Implications

MIDWEST CONFERENCE

1. Role of the Regional Labs
2. The Future of the Profession
3. A Piercing Look at the Compact for Education
4. Multi-district Cooperative Program
5. Hardware and Software in Education

MIDSOUTH CONFERENCE

1. Science Speaks to Education
2. Shaping and Influencing Public Education
3. Changing Relationship: Teachers and Administrators

Some of the above titles do not convey their content, others are obvious. Many of the papers convey the impression that local administrators are becoming increasingly concerned about internal forces leading to change. External forces pressuring for change of the existing system include the U. S. Office of Education, industry, and state Departments of Education.

The relationship between the locus of authority and the accumulation of information is an important one. Executive Managers have long been aware of the potentialities of accrual of masses of data pertinent to all phases of an operation. Not only can decisions be made more effectively, but control and authority are either shifted or reinforced. A close surveillance of budgets and performance can be maintained.

Several problems specific to educational administrators come readily to mind.

1. Does centralization of educational data lead ultimately to

centralization of authority? Implicit is the threat of loss of local autonomy and/or authority for many school districts and administrators.

2. Accumulation of data in one central office accessible to only a few people permits narrow control of the decision - making process, and surveillance of ineffective decision making. Information in one location could, without difficulty, become classified. The effects of such centralization should be evaluated fully.

3. The issue of the invasion of privacy inevitably arises. If comprehensive school records on individuals can be maintained easily for extended periods, who should have access to this data? How long should the data be kept? Should records of student's difficulties, of interest to teachers and ancillary personnel during school years, be preserved after they have lost their original utility? The whole issue of privacy becomes a major one when one considers that privacy is the most effective weapon the individual has against an all-powerful state. "Information which is inconsequential and trivial today could be used tomorrow by different men with a different set of values to destroy us". - Robert H. Davis - Systems Development Corporation.

4. Through computers the operation of each individual school suddenly becomes available for close scrutiny by central administration officers. An individual's performance can be examined closely, and compared with others in similar positions. Such action is conducive to economic efficiency and may be justified as research, but improper use leading to unnecessary pressure with personal or group disadvantage may be damaging to our national values and to group morale.

Part II: Administrative Considerations: CAI

1. The administrator considering implementation of CAI must be prepared to conduct a well-planned program of orientation in advance of expected use in the classroom. The dimensions of the problem can be illustrated with the experience of the Fox Lane Middle School, Bedford, N. Y.

Prior to installation of Dial-Access in that school, a group of teachers characterized as sophisticated and progressive were selected to design the program. The plan posited that, with involvement in program preparation, the teachers would embrace more readily the new educational technology. The teachers gave long hours of extra service time with indications of enthusiasm and willingness to incorporate the new program into their teaching. The following fall, when the programs were expected to be operational, the equipment remained unused. The administrative staff had failed to recognize that the new teaching techniques demanded new patterns of classroom organization for the teacher.

The teachers in the Fox Lane Middle School still viewed themselves as the dispensers of information. The teachers had not been assisted in altering their roles in the classroom. With a machine capable of dispensing information, the teacher's role could now become that of providing situations conducive to improved student learning. Neither teachers nor administrators had considered the possibility of seeking new relationships between, pupils, teachers, and materials.

When the purpose of CAI becomes that of individualizing instruction, a second basic teaching pattern requires alteration. The traditional teacher prepares lesson plans and subject matter units for group assignment, participation, and projects. Homogeneous grouping based on achievement level within classes is still conceived of in terms of small groups. Until CAI can be designed for small group manipulation and participation, teachers using CAI must plan and program for each individual student in addition to reassessing their basic function in the class. This may of course constitute a significant role for the teacher in the face of individualization via the computer.

Effective orientation of teachers to altered classroom roles is the responsibility of the educational administrator.

2. A second major factor is the determination of whether education via CAI is to be individualized to a degree necessitating free flow of children to new levels of achievement at unpredictable rates. Experimentation with ungraded classes, of course, continues in many primary and elementary schools without regard to computers. A totally individualized instructional system might lead to significant changes in school entrance and leaving laws. Normal ages for secondary school and college entrance may be affected. Educational leaders may need to consider social developmental patterns as added factors in determining an optimal educational pace.

3. Since neither educational research nor industrial research has validated the effectiveness of CAI in the classroom, the administrator must evaluate CAI programs partly on the basis of those currently in operation. The administrator should consider three levels of computer use in schools:

a. Computer courses to orient business students to computer technology prior to leaving high school. (Ex: the Abraham Lincoln School, Brooklyn, N. Y.).

b. Computers on campus for students to use in problem solving related to mathematics, science, or mechanics. (Ex: Bethesda-Chevy Chase High School, Bethesda, Md., Walter Johnson High School, Bethesda, Md. Teachers are not involved in these programs).

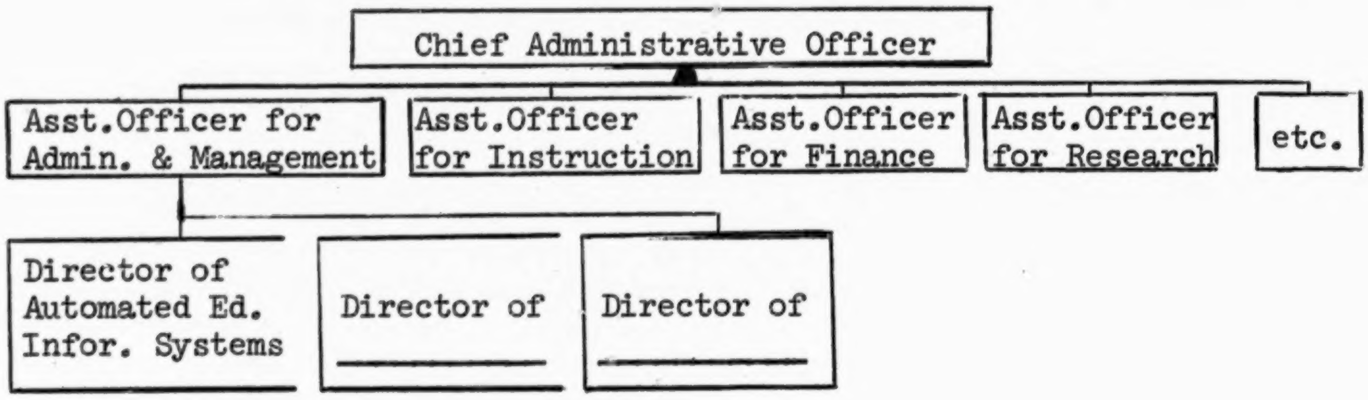
c. Programs in which the computer is used to instruct in subject matter. (Ex: Dartmouth College, Hanover, New Hampshire conducts mathematics instruction in local secondary schools. A reading program is conducted by the Responsive Environment Corporation in the New York City school system).

Part III: Problems to be Considered Before and After Installation of EDP or CAI*

1. Location of the computers. The physical location of the computer is significant not only for practical considerations of proximity to classes or offices with major blocks of time allotment, but for the dynamic impact on staff. Computer equipment installed in the center of the administrative offices may alienate the instructional staff. The converse may also occur. Equipment located in remote regions of a plant is not only inaccessible, but may inadvertently express the attitude of those involved in its placement.

Totally new facilities may be provided for housing of various technological aids within a school system. Modern school architectural advance should be revised. Some teachers feel strongly that the computer should be in the class as opposed to time-sharing or teletype installations. These teachers point out the motivating effect on students of having the machine present.

2. Technical competence of current staff requires careful assessment. Some administrators may discover that their staff is already knowledgeable in the operation of the new equipment. Others will need to depend mainly on industry to provide programming and operational technology. The juxtapositioning of an office or instructional staff to industrial engineers or analysts requires tactful handling. A third alternative is to create a new office division or computer center. An illustration of an administrative design incorporating a division of Automated Educational Information is presented below:


Chief Administrative Officer
Asst.Officer for Admin. & Management
Asst.Officer for Instruction
Asst.Officer for Finance
Asst.Officer for Research
etc.
Director of Automated Ed. Infor. Systems
Director of ____
Director of ____

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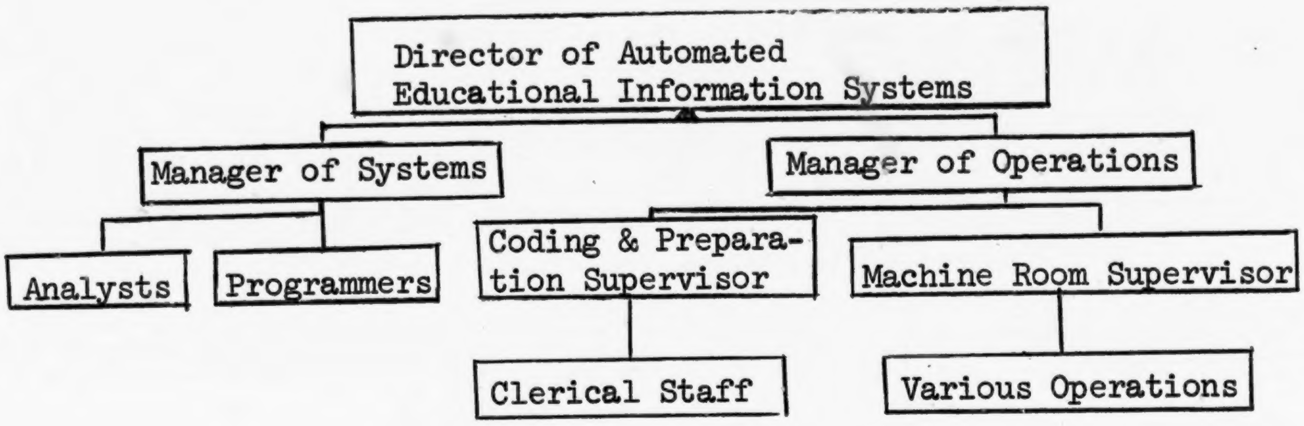
*Cost is the most obvious consideration. A discussion of computer costs has been presented in another paper.

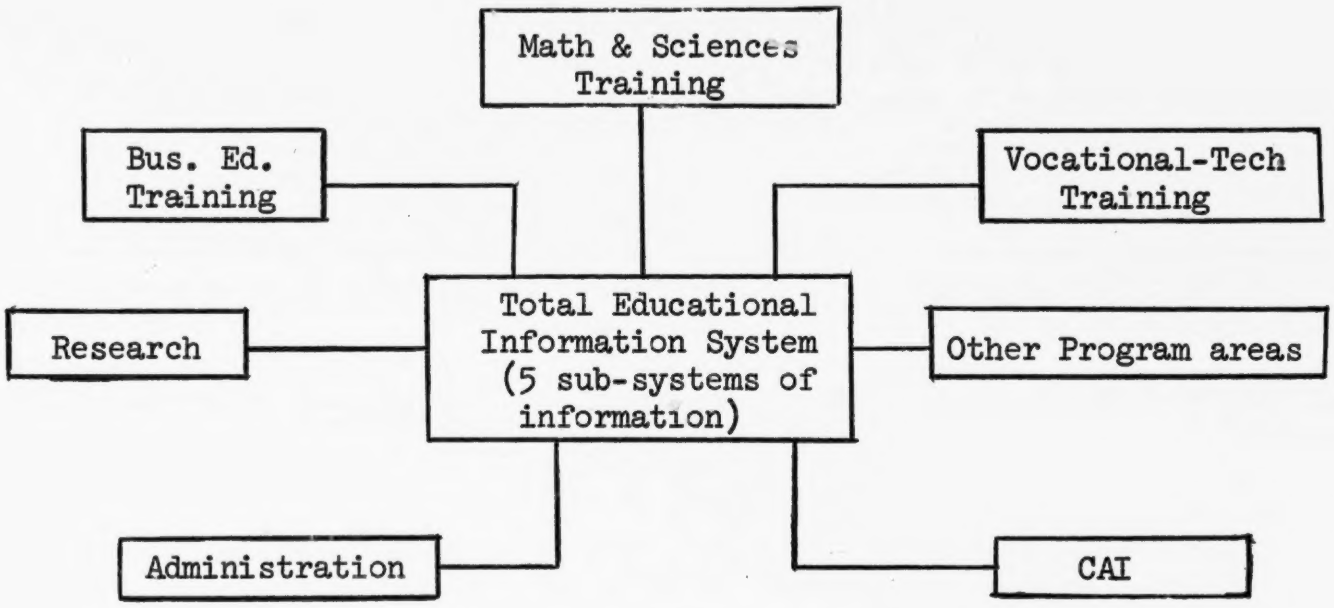

Director of Automated Educational Information Systems
Manager of Systems
Manager of Operations
Analysts
Programmers
Coding & Preparation Supervisor
Machine Room Supervisor
Clerical Staff
Various Operations

3. Programming for CAI and/or EDP. Related to the problem of staff technical competence is the provision of "software", or programmed materials for the computer. The hardware itself is not sufficient. Updated programming needs must be met by the school or by external sources. The price of the hardware has been roughly estimated as one-fourth the total cost of a school computer system. There are several alternatives. Some industrial developers are attempting to provide the programs needed. Instructors, assisted by other clerical staff, may acquire the skills necessary to develop programs. External agencies specializing in program development are already being set up. EDP may have to be constantly reviewed or restructured. Industry may not want to assume extended responsibility. The concept of the key man is useful. An individual skilled in computer technology and educational concepts may be employed to train office personnel and teachers.

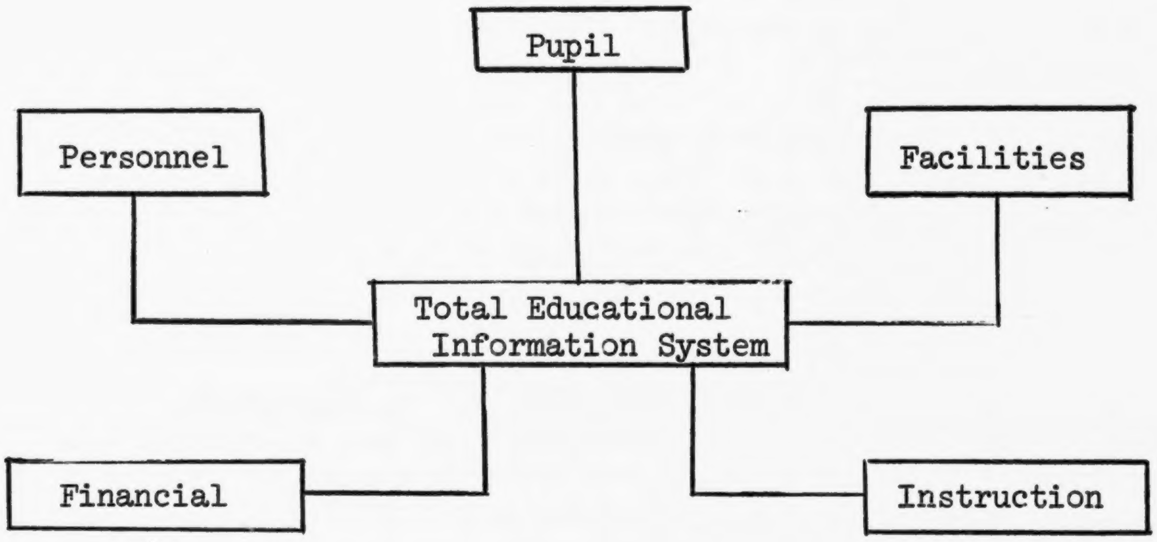
4. Competence of the Administrator. An educational information system designed primarily for research purposes will require an administrator with a high level of sophistication in computer technology and research design. This would be true if even a minimal level of efficiency and sound evaluation is desired. At a more advanced level, the administrator would develop the skill to use the computer to search for problems.

5. Consideration of the single-purpose computer or total systems approach. A school administrator will need to explore potential uses for the computer throughout his entire school system. With time-sharing increased, costs per use, decrease. The Administrator must consider the saving in unit cost as well as the increase of overall consolidation of information available via the use of a multipurpose system.

The two charts below illustrate organizational designs of an educational information system and related subsystems.


Math & Sciences Training
Bus. Ed. Training
Vocational-Tech Training
Research
Total Educational Information System (5 sub-systems of information)
Other Program areas
Administration
CAI

* *


Pupil
Personnel
Facilities
Total Educational Information System
Financial
Instruction

Conceivably the community could be included in the school computer system or the converse. Integrating the needs of community agencies with those of a school system may reduce the cost of computer time for both school and community. More important, some information of value to many agencies can be shared, i.e., demographic and economic information. The issue of authority and control must be examined thoroughly to insure maximum cooperation of both school and community administrative officers.

6. School administrators and educational leaders need to consider the impact of computer technology on school size. As the computer is applied to more administrative and instructional uses, computer costs decrease. Thus, the introduction of a computer system may produce pressure for larger centralized school

districts or educational units. The advantages and disadvantages of the larger schools should be weighed. In 1964, Barber and Gump reported that the average number and kind of classroom activities in high schools was twice as great in the small school as in the large. Their findings also revealed an inverse relationship between school size and amount of individual participation in non-classroom activity. These conclusions are not cited as final, but to underscore the need for research into optimal school size in relation to computers use.

7. Computer Systems and Educational Research. The school administrative officer considering computer installation primarily for research purposes should consider the problem in the total context of educational research.

N. Fatter of the University of Indiana stated at a recent conference for educational administrators that educational research, to date, compared with that of other scientific disciplines is trivial. Fatter points out that education does not have any sound body of theory guiding educational researchers to deal with criterion problems. Computers cannot offer a set of values or principles, only a means of handling data. The obverse might also be considered.

The computer offers some of its greatest uses in the field of research. Perhaps through the computer sensitivity and insight into student-teacher interaction, and the process of learning which are necessary for educational research will become possible.

8. Longrange considerations. The effects of CAI over an extended period should be considered. The computer has limitations. Those limitations are the rules by which its responses are governed. Man is generally capable of a wide range of creative responses. If the computer must, in effect, eliminate the extremes of the normal curve of responses because the computer's responses must by its very nature be limited, what might the longrange effects on the distribution of human skills be? Further, the computer system is based on efficient, rational thought. Rationality is not always conducive to creative thought. The longrange effect might be to stifle creative thinking, whereas education should provide the impetus for creative thought.

This paper was prepared by an experienced teacher who has become deeply involved in the education of teachers and in the process and problems of innovation and change in education. Her views may reflect some of the experience and perhaps frustration of having been a "soldier" in what is at best a slow moving army.

PROBLEMS OF TEACHER EDUCATION AND ORIENTATION

Judith Leitner

The Subcommittee on Economic Progress of the Joint Economic Committee of the U. S. Congress conducted hearings on the issue of technology in education. Representatives from industry and education appeared to state their views on the future role of technology in education. For the purpose of having their views receive due consideration, speakers from industry and education ranged from conservative positions to considerable "bullishness" in their projections. Many of these positions are expressed in the current folklore and advertising. They may therefore tend ultimately to skew our understanding of and perhaps the reality of the delicate and sophisticated interaction of technology and education that is repuired if education is to play the new role that is almost universally promised. The key implications should be reviewed.

Certain concepts have been misconstrued to perpetrate the myth:

1. that because computers provide a new scientific tool and method for education they will therefore transform education into a science;
2. that the computer will replace the teacher in the classroom;
3. that other areas of culture are being automated, therefore it follows automatically that education should or needs to be automated;
4. that computers will produce a uniform product in the form of a "standard student";
5. that industry will solve the problems of education;
6. that since we are experiencing an information explosion education must rely on the computer to impart this mass of information to students. We would prefer to examine the educational system in its entirety.
7. new capacity to impart information to the learner is sufficient to revamp education.

Summary: Such myths serve only to frighten the conventional educator instead of opening new horizons to them.

There is a potential contradiction in discussing in the same breath the individualization of education and the completion of uniform curricula albeit at different speeds of learning. Neither computers nor teachers can obtain such uniformity nor is it desirable. This issue has real implications for the development of educational objectives.

"Can Teachers Survive the Educational Revolution?"[1] This quote is representative of the negative messages directed at teachers with respect to the use of Computer Assisted Instruction. The message points clearly to a problem. Will it further complicate the development of education and CAI? Are the teachers themselves responsible for a problem that obviously exists?

Literature is permeated with the concept of teachers being in competition with the machine, that the very role of the teacher is threatened and that a victory for one will be defeat for the other. In a sense, it is somewhat remarkable that teachers appear to be so defensive on this issue. Is it possible that their own role definition is so narrow as to merely imply they are repositories and dispensers of information? Or, is it possible, that negative reactions are based on stereotyped view of automation because of a lack of sophistication concerning CAI?

It seems appropriate to comment on the field of education and its professional status. There may be a consensus, both from within and without the profession, that there is a considerable lag between new knowledge and its eventual application in the classroom. One encounters the assumption that the lag ranges from 25 to 50 years. Along with this is the charge that educational practitioners are notorious for using ideas that have long since been proven unsound in the research laboratories.

Although the following example may seem far afield, it will be drawn into the general context. In the 1950's racial segregation came more to the forefront as an extremely important issue. In the first paragraph of the National Education Association Code of Ethics it is stated that all teachers should treat all children equally, regardless of race. Neither the NEA, nor any of its state or local affiliations, took a stand on any of the segregation cases. The point is not that teachers did not eliminate racial segregation, but that they did not take a stand on what surely called for some sort of professional initiative.

The same process may be taking place with CAI. A powerful force is available and education and the teacher may, by inaction or resistance, miss the opportunity to leave their mark on the new development. Both innovations are inevitable of some application and both are highly charged areas emotionally.

CAI then becomes important in two respects:

a) in the specific sense of the need for new instructional media to help in the teaching-learning process, and
b) in perhaps what may, in fact, be a crisis in education, relative to the very status of the profession itself.

As one surveys the field of CAI, both in the literature and in discussion with those involved, one thing becomes quite obvious. We are faced with the problem of a very low participation of educators, in general. There are examples of industry approaching the school systems with ideas, instead of the other way around. Since industries' context and purposes are frequently different from those of education we may detect the beginning of a problem.

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[1] Loughary, John. Phi Delta Kappan, January 1967, p. 204.

The industrialist and the technologist are relative newcomers to the field of education. They will probably difine their own responsibilities unless educators begin to delineate the contribution they expect from industry.

Research and development in CAI have been largely devoted to the improvement of the hardware. Experts, such as Dr. R. Louis Bright of the U. S. Office of Education, feel that innovation in software is the critical requirement at this time. There is a definite need for educators to develop a "curriculum" for the computer. Systems of computerized education cannot possible deliver all that is promised without more aggressive action in this area. There is also the realization that hardware and software are not enough. Systems still need people and in order for CAI to be successful there is a need for positive receptivity on the part of teachers. Consider what happened to Educational TV. It never really reached its envisioned success. There is still the problem of the relationship of the system to the human needs of both the teacher and the learner. Teachers have managed to impede its development by just not using the equipment after it is installed in schools. When one considers that CAI involves an even greater investment of both time and expense it becomes important that its success or failure should not depend upon a haphazard approach.

The point has been raised that CAI is a subject to which educators should address themselves - a topic on which they should develop an opinion objectively. This would involve a knowledge of what is involved in CAI.

There are two basic way computers can be used in schools. The first is for the administrative chores that even a teacher must face, such as record keeping. The second is a more direct assistance in instruction. The latter appears to be the focus of most concern.

There are three levels of interaction between the student and the computer:

a) The drill and practice systems are the simplest level. The computer is used purely as a supplement to the teacher's instruction. In this case the teacher has already presented the conceptual aspects of the lesson and even perhaps some classroom practice.

b) The "tutorial" system actually does some of the teaching.

The advantage usually associated with this aspect is that the teacher is freed for more complex and demanding tasks such as the individualization of instruction.

c) The most complex level is the one that allows for a dialogue between the student and the program.

There is also a fourth level, however not so distinct. That is a problem-solving technique, whereby the student is essentially on his own, from initiating the problem to constructing and implementing the program. In some cases the students teach themselves the language with which they "communicate" with the computer. It should be said that this has been met with considerable enthusiasm by the students. This writer has had the opportunity to observe the high level of investment of high school students involved in just such a project.

The use of the computer appears to be an advanced outcome of the general field of programmed instruction. Since there has been no significant research on teachers' attitudes toward CAI, one must determine:

a) whether it is appropriate to generalize from the conclusions drawn from research on Programmed Instruction, or
b) is CAI a qualitatively different system.

If one assumes the former then Programmed Instruction can, in a sense, be viewed as a continuum. At one end is the programmed textbook and at the other the "shared time" computer-based systems with multiple student stations. At any of these levels the positively oriented teacher is a necessity, the negatively oriented one an almost insuperable obstacle. There has been some investigation of teachers' attitudes toward various aspects of Programmed Instruction if we may assume the generalization to CAI.

One researcher, Sigmund Tobias, considered that the designation of programmed devices by technological labels (automated instruction, mechanized tutor, teaching machine) reinforced the concern regarding the mechanization of the learning process. He states,

> the word "machine" has acquired a heavy emotional burden. The same burden is now rapidly piling up on such words as automation. Thus the phrase automation of education with teaching machines represents such a summation of horrors for some people that it blocks intelligent inquiry into the merits of teaching machines.[2]

Tobias conducted a study to determine teacher attitudes toward a set of terms describing instructional devices. Of particular interest was whether the use of technologically oriented vocabulary fostered particularly unfavorable feelings.

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[2] Tobias, Sigmund. "Teachers' attitudes toward Programed Instructional Terms." Journal of Programed Instruction, Vol II, 1963.

The group of subjects included 23 elementary school and 27 junior high school teachers. The 36 men and 14 women had a mean teaching experience of 3.57 years. The subjects were recruited from graduate education courses.

The subjects were asked to rate nine instructional devices on six bipolar scales. The scales were selected on the basis that they were likely to elicit value judgments. The following scales were used: Good-bad, Worthless-valuable, Fair-unfair, Meaningless-meaningful, Wise-foolish, and Reputable-disreputable.

There were three categories of instructional devices: a) hardware and automation, b) those emphasizing programming, and c) some traditional instructional devices similar to programmed materials. The nine terms were: 1) automated instruction, 2) programmed text, 3) exercise book, 4) mechanized tutor, 5) programmed instruction, 6) flash card, 7) teaching machine, 8) tutor text, and 9) workbook.

It was found that teacher attitudes are more negative toward terms describing programmed materials than toward similar labels describing instructional devices of a traditional sort. There was a more positive attitude elicited when the names stressed programming rather than hardware or mechanization. The investigator felt that the finding of significant differences between presumed synonymous terms, such as programmed instruction and automated instruction suggests that the differences lie in the teachers' feelings and not in differences between the terms.

The data indicated that teachers have generally unfavorable attitudes toward programmed materials when described in technological terms. Tobias states that his data completely "unsupport" the claim that teachers are eager to experiment with machines due to the culture's worship of machines. This is interpreted by Tobias to mean that the terminology of "mechanics" may well bias the teacher against programmed instruction and, therefore, may inhibit an intelligent evaluation of its merits.

Tobias felt that there was not enough data to support the contention that teachers feel threatened by replacement by the machine. He then conducted another study to refine this conclusion.[3] In this study, of student teachers, the sample was quite small and does not lend itself to many generalizations. However, there were some important issues raised.

He felt there was evidence to support the concern that teachers do, in fact, see themselves as threatened by the introduction of some of the newer media. He tested the subjects both before and after their exposure to information regarding programmed instruction and noted that the negative reaction appeared to be only slightly

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3. Tobias, Sigmund. "Teaching Machines and Programed Instruction." AV Communication Review, Spring, 1966.

affected by the additional information. It was suggested, however, that the attitudes toward equipment involving automation are probably open to modification.

Tobias introduced another important factor. The results of the last previous finding and the prior study strongly suggest that the reports of highly positive attitudes of teachers toward programmed instruction fail to differentiate between the reactions to programming and to automation. Analysis of research methods employed in recent learning research tends to substantiate this principle.

Lawrence Stolurow conducted a study of students in teacher education.[4] He also found that they considered teaching machines a threat to teachers. He felt it was a somewhat ominous picture of the future for programmed instruction if even fledgling teachers hold to these opinions. Based on his research, he felt that a better dissemination of information will aid the progress of automated learning.

Those who are advocating the progress of automated learning/ instruction may indeed have based their opinion on the a priori assumption that CAI is what education needs. However, if it is concluded that policy making should be in the hands of the educators, then they should have a role in making the decision. It appears that most of the impetus for the use of CAI has come from industry. In one program negative attitudes of teachers were handled by a self-selection process. Those teachers who didn't like it left the school. The results of research from this project will reflect the positive attitudes of the remaining teachers. In another school system the responsibility for the training and orientation of teachers in the use of CAI has been motivated and carried out by a computer firm. It is very possible that they are conducting a sound program. There is little evidence that the "halo" or the "Hawthorne" effect have been dealt with or that other controls have been provided.

If we assume that there is a necessity for modification of teacher's attitudes toward automated learning and that this modification is possible, then there are various implications for educators.

One method noted was a better dissemenation of the research and literature in the field. There is a recognized need for this and the USOE has developed the Educational Research Information Center (ERIC). At the present time, they are investigating the various sources of information both from within and without the field of Education.

In-Service education is another way of orienting teachers toward new techniques. However, educators have considered the possibility that in-service education may not be the best way of effecting change. It does remain one of the only ways to reach teachers who are already in the field.

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4. Stolurow, Lawrence. "Implications of Current Research and Future Trends." The Journal of Educational Research, June-July, 1962.

Attention has been given to the implications of a leadership role at the university level for those dealing with the education of teachers. There is the possibility at this level of teacher education for both didactic and practical learning regarding CAI. There are already examples of universities becoming involved in CAI in school systems, but it is not really a general pattern in terms of Education Departments.

One of the trends in teacher education appears to be the view of the teacher as an educational diagnostician - a prescriber of learning. An important aspect of this would be the teachers' ability to communicate with ancillary personnel to gain knowledge of both the child and the available approaches to guide learning. With respect to CAI, the teacher must be able to communicate needs to the technologists so that their concepts can be transferred to application in the classroom. This would assume that the teacher has some knowledge of the roles of systems specialists, programmers, and engineers. There is also an inherent responsibility for the technologists to gain a thorough understanding of both sides of the teaching-learning process. Perhaps the overriding requirement is for both groups to achieve the kind of enduring communication that will make the skill and productivity available in the service of education.

This paper was prepared as a supplement to other currently available material describing the fundamentals of computer operation and programming. We have stressed areas not extensively developed in other documents, notably some of the problems of computer language. It was used as part of a mosaic of information on computer operation and software which included Computers and the Human Mind by Donald Fink, the Entelek outline by Albert Hickey, et al., and the briefing paper presented to the seminar by Dr. Louis Robinson.

COMPUTER LANGUAGES

Gary Larsen

The Computer System

A computer system consists first of all of a computer and its peripheral devices. Peripheral devices are the machines through which data is transmitted to or from the computer. Thus a card reader reads the punched IBM cards containing a program or data, translates the punched information into an appropriate form, and sends it to the computer. A printer, on the other hand, receives data from the computer, translates it into the proper sequence of characters, and prints this information out. A magnetic tape drive is able to either read information from a tape and send it to the computer, or to receive information from the computer and write it on a magnetic tape. A disc drive is able to do the same with magnetic discs. Finally a flexowriter or teletypewriter is able to take the characters typed out by the operator, translate them into the proper signals and send them to the computer, or to receive information from the computer, and translate it into a sequence of typed characters. All of these are more or less standard equipment. In addition there may be other devices, such as a Cathode-Ray Tube (like a TV tube or radar scope) audio-visual equipment, and so on. All of these and the computer itself constitute the hardware of the computer system.

Another and equally important part of the system is what is called the software. This consists of the programs written to control and operate the computer and the peripheral devices, or the hardware The programs, or software, are in effect the "mind" of the system as the hardware is its "body".

In the realm of software, there are many kinds of programs. There is first of all the control or executive or monitor program which exercises overall control of input and output of information, and prevents a complete breakdown of the computer in the event of the failure of any of the other programs. It also checks and tries to correct for any hardware failures, and tells the computer operator if possible the nature of any hardware failure. For instance, when the printer runs out of or is about to run out of paper, the control program senses this, tells the operator through the flexowriter, and then waits until the operator has put in more paper. The control program then allows the computer to continue whatever it was doing when it stopped. In a time-sharing system the job of the control program is much more complicated because besides doing all the above, it must schedule the input and output and internal processing time allowed for each terminal of the perhaps dozens of terminals hooked into the system. This means interpreting the input for each terminal, sending it to the right program in the computer, and sending the output to the right terminal, all of this fast enough so that each terminal does not have to wait more than a few seconds. Time-sharing systems are possible because computers have been developed which can do simultaneous input-output processing. By this it is meant that a computer can be reading information into one part of the computer, while at the same time another part of the computer is processing other data and preparing the output to be transmitted later. Thus time is saved because a lot of internal processing can take place while the data for one terminal is being read or written.

Another type of program is the utility program which is actually a set of little programs written to do the many little off-line jobs necessary in a computer center. Thus one such program might be to simply print out the contents of a magnetic tape. An off-line program refers to a program which is used when the entire system is not in operation. A program, for example, designed to print out the record of the day's activity on a time-sharing system used after the system has shut down for the day is referred to as an off-line routine or program.

A third type of program includes the assembler, compiler, interpreter, or translator programs. These are essentially aids to the programmer.

Finally there are the simple programs written by the users of the computer designed to do specific jobs, such as a statistical analysis, the solution of a differential equation, or an audit and updating of a firm's records. These programs are the primary justification for the computer system, but they are by no means all there is to a computer system.

Programming Languages

As you may be able to imagine, it is quite a job to write all of these programs. In order to make this job easier, what are called programming languages have been developed. It will be the primary purpose of this paper to explain first how a programming language makes the job of programming easier, and then to describe in general terms some of the characteristics of the language developed specifically for computer assisted instruction. But first it is necessary to go into some detail about the internal makeup of the computer itself.

Relation to Internal Program:

A computer is made up of two parts; the processing unit, which does the actual work of the computer, and the storage area called the memory, wherein are stored the programs currently being run, and the data being used by the programs. The programmer is usually only interested in the makeup of the storage area, since that is where the program is, and the processing unit is controlled completely by the program. That is, the program tells the processing unit what kind of processing to do, and in what order to do it.

The memory of a computer consists of what are called in computer jargon, words or bytes. Bytes are actually parts of "words", but they are often more meaningful as the unit of storage capacity than are whole words. Computer words are not to be confused with what is usually meant by words. All computer words are made up of the same elements, bits. They are physically all identical. On the other hand each "word", and each byte has its own unique numberical address within the memory space. Thus the first "word" in memory has the address of one, and the thousandth "word" has the address 1000. Any "word" in memory, and likewise any byte, can be referenced by its numerical address.

The elements of a computer word are called bits. These are small electromagnetic entities which have two possible conditions or states; they can either be "on" or "off", or positive or negative. Because of this two-state property of the bits in a computer word, a "word" can be conceived as a physical representation of a binary number, a number to the base 2. (See glossary for a fuller explanation of binary numbers). Such a number system has only two digits, one and zero, so that an "on" or positive bit can represent a one, and a negative bit can represent a zero. A computer word then, can be thought of as a row of ones and zeros.

The processing unit of a computer is able to set or change the bits of any "word" in the memory area, and also to sense or "read" which bits in a word are ones, and which are zero. It is this ability of the processor to read the contents of a computer word and to be directed in its processing by the bit configuration that enables a program to control the operation of the computer. A program in the computer is simply a sequence of computer "words" so set that they cause the processor to produce the outcome desired by the programmer. Each of those "words" contains what is called a computer instruction, that is, a specific operation to be programmed, and the addresses of the computer words associated with that operation. The kinds of operations a computer performs are generally; 1) arithmetic operations (addition, subtraction, multiplication, division), 2) data manipulation operations such as moving the contents of one computer word to another computer word, 3) compare operations (equal, not equal, greater than, less than), 4) branching and transfer operations, which control the order in which the instructions are processed, and 5) input-output operations, which are concerned with transmitting data to or from the computer. Each of these operations is specified in the instruction word by a specific configuration of certain bits, usually the first few bits of the word. The rest of the instruction word is used to express as a binary number the address(es) of the word(s) associated with the operation. Thus, for a branch operation the address is a specific "word", and the address would specify the "word" to which the processor is to branch. An addition instruction would contain the addition operation code, the two addresses fo the computer words to be added together, and possibly a third address of the "word" in which the result is to be stored.

The data on which the program operates can be expressed either directly as binary numbers, or in the case of symbols as coded bit configurations of a fixed length. Thus, letters, punctuation marks, numbers considered as characters, and special symbols may be expressed as different configurations of eight bits, each symbol having its own unique combination of ones and zeros. It is in connection with the manipulation of these symbols that bytes become important, for one byte corresponds to the number of bits necessary to express one symbol. Thus by addressing individual bytes, it is possible to manipulate individual symbols.

Types of Languages:

A program, then, is to the computer a sequence of computer words containing instructions encoded in binary bit configurations. It is this sequence of instructions that it is the programmer's job to specify. The most direct way to do this is by specifying exactly which bits in each word should be set to one, and which bits should be set to zero. Such a direct approach, however, is a difficult and time consuming task. Few if any programmers are forced into writing programs in this way. Perhaps the original program on the original computer had to be written this way, but nowadays even the original program for a new computer is written with the aid of another computer. The first program written for a new computer is generally the assembler program, and the inputs to this program are called the assembly language. This is the first step towards making the programming task easier. In an assembly language the instructions no longer have to be specified as binary bit configurations. Instead they can be designated more or less by name, or at least an abbreviated name. Likewise, specific computer words can be given symbolic names or addresses and referred to in an instruction by these names. The assembly program then interprets the symbolic instructions and generates the proper bit configurations in the computer words themselves. Thus, the programmer's job is made easier in that he can more easily keep track of what he is doing in his program.

Using an assembly language still requires, however, that each instruction in the program be specified. Writing a program could be much easier if it were possible to write it simply in terms of the functions the computer is to perform, instead of the specific operations. Thus if it were possible to write out the entire equation in a scientific problem, rather than specifying each operation of addition, subtraction, multiplication, and division in the equation, the programming would be even easier. It was to allow this kind of programming that the compiler program and the compiler language was developed. With the comiler language it is possible to state in a more normal straight-forward way what the computer is to do, and the compiler program will interpret these statements and generate the proper internal coding to do what the statements say to do. In this case, however, several computer words containing several instructions may be generated to take care of one statement in the compiler language.

Many compiler languages have acquired a life of their own independent of any particular compiler program. A compiler program is specific to a given computer. It is written in terms of the instruction set of that computer, and it generates programs made up of these instructions. It can be designed, however, so that the in-puts to it, the language, conforms to a standard. Thus the FORTRAN language has been accepted as a standard scientific language, and most compiler programs written for scientific computers are designed so that they can accept the FORTRAN language. The quality of the object coding or the final program as it appears internally to the computer is more dependent on the quality of the compiler program than it is on the compiler language. Thus the same program written in a compiler language can result in very different object programs on different computers. It is even possible that the results of the program will be different on different computers.

FORTRAN is the best example of a machine-independent language. Since it was designed for use by scientists and engineers, this language was constructed so that the statements in it resemble mathematical equations. Thus it is easy for a scientist to translate a set of mathematical equations into a FORTRAN program.

Another machine-independent language is COBOL, which was designed to make it easy to write a program to solve a business problem such as updating a bank's records. Its statements resemble normal English statements. COBOL, however, is not as universally accepted by business as FORTRAN is by science and engineering.

This is in part because COBOL is a newer language, and all the problems in it and in its compiler programs have not been completely ironed out, and in part because alternatives to it, although not as easy to use, have become established in many places.

CAI Languages

These two languages cover the two major users of computers, business and science. They are not however, the only languages available. Many individual corporations and institutions have developed other programming languages for various purposes, one of which is Computer Assisted Instruction. There are in all about 18 different languages being used in some way for CAI. This writer has come into direct contact with seven of these different languages. The languages, with a brief description of each is as follows:

BASIC - A compiler language developed by General Electric for its Dartmouth time-sharing system. It is basically a simplified computational language.

TELCOMP - A language developed at MIT on the model of JOSS, a language developed by RAND. It is also primarily computational, but it has the added feature of allowing direct computation without first writing a program.

COURSEWRITER II - The language developed by IBM for use with its 1500 CAI system. It is primarily an assembly language and an instructional language.

PLANIT - The System Development Corporation's instructional language for use in its time sharing systems.

INFORM - Philco's instructional language to be used in Project CROW involving four Philadelphia high schools.

Basic Source Language - RCA's instructional language to be used at Stanford.

MENTOR - The tutorial language developed at Bolt, Baranek & Newman in which the student, besides answering questions asked by the computer, is able to ask the computer questions.

These seven languages may be classified into three groups.

There are first the languages which are primarily computational rather than instructional. That is, their use is as an adjunct to the actual teaching situation rather than as the central part of it. In this class belong TELCOMP and BASIC. They can be used by the student in the first place to help him in solving a problem. In this respect TELCOMP is better than BASIC, since with TELCOMP the student can do a simple arithmetic problem such as 2+2= ? without first having to write a program. In BASIC the student would first have to write a program and then execute it to get the answer, whereas in TELCOMP the student has simply to type out 2+2= ?, and the computer will return with 2+2=4.

More creatively these languages can be used by the student to write a program to solve a general problem, such as a program to extract the roots of any quadratic equation. Such a task for a student has obvious educational value, for in order to be able to write a successful program, the student must be completely clear about the logic behind the solution to the problem. Beyond the specific problem which he cannot help learning, the student also learns the necessity for clear logical thinking in an immediate, forceful way.

The kinds of programs that can be written with these languages is not limited to mathematical problems, however. The variety of programs that can be written is limited only by the student's imagination. One may write programs which play games. Programs making the computer the dealer in a game of black jack are common. More complex programs could be written to play checkers or bridge. A student may find highly practical uses for the computer. For instance a high school student using BASIC has written a program which calculates the best lighting system for the school stage, given the desired characteristics for any play.

These two languages are only auxiliary aids to the main teaching task, however. The second group of languages are more central to CAI since they are specifically instructional. IBM's COURSEWRITER, SDC's PLANIT, Philco's INFORM, and the language used by RCA belong in this group. The general conception of lesson construction is the same for all four. A block of subject matter is presented to the student and a question is asked about it. Depending on the nature of the student's answer, more questions are asked, another block is introduced, the question is repeated, or some entirely different material is presented. This is the primary advantage of computers. By skipping ahead in the lesson sequence, going back to an earlier part, or introducing a special remedial sequence, the computer can be sensitive to the requirements of each student. A human teacher, of course, is able to base his decisions on far more cues than the single response, but lesson sequences probably could be constructed which are as good as some teachers, and computers have certain virtues which humans lack, such as infinite patience and constant availability. Another advantage of a computer over a human is that the computer has a complete record and instantaneous recollection of everything the student has done throughout the entire course. SDC's PLANIT makes especially good use of this in that it is able to decide where to go next on the basis of the whole history of the student's errors, rather than on just the last error. It is left to the programmer's discretion as to how much use is made of this facility. It may become possible to do this in COURSEWRITER II, but not with the language as it exists now. It is not clear at all how this could be done in the other two languages. All of these languages, however, keep a record of each student's performance so that it can be analyzed later. This data can be used both to evaluate the student's performance, and as data for research in educational theory.

None of the four above languages is especially easy to learn, or to work with. A thorough knowledge of the particular language and its peculiarities is essential to the construction of a really good lesson sequence. This is not so true of the last language, MENTOR, which stands in a class by itself. MENTOR is as close to English as it is currently possible to get. The reason MENTOR is in a class by itself, however, is because it is the only one currently which is able to carry on a real dialogue with the student. That is, the student can ask questions as well as answer them. The SOCRATES system was a predecessor to MENTOR, but MENTOR has apparently completely superceded it. IBM also is apparently trying to develop some dialogue-like features in its COURSEWRITER language, but this is still in the future. MENTOR can allow the student to ask questions because it can determine the appropriate answer by the context or part of the lesson sequence in which the question occurs. Thus in a program written to train medical students in making a medical diagnosis, a guess at the patient's illness before the patient has been examined fully is rejected by the computer, and the student is told to stop guessing. Later on, however, when a guess is reasonable, it may be accepted as justified. Having this feature in a language also requires a large dictionary of possible questions and guesses.

The relation of the languages to time-sharing systems in general varies. Four of these languages, BASIC, PLANIT, TELCOMP, and MENTOR are part of larger time-sharing systems which can handle other languages, and therefore provide more services to the user. Philco's INFORM, RCA's language, and IBM's COURSEWRITER, conversely, were all designed by computer manufacturers as part of their entire CAI system. As such they are able to make use of devices other than the teletypewriter, such as the CRT and audio-visual equipment. Because the manufacturer knew what the hardware was going to be in the system, he could design his language to take full advantage of its possibilities. The disadvantage is that such systems remain mainly limited to CAI. This is strictly true only of the IBM 1500 system, since it is the only one with its own specially designed computer; but the problem is still at least temporarily present for all three of these systems.

BASIC, PLANIT, TELCOMP, and MENTOR are limited in that the only means of communication with the student is through the teletypewriter. There is no CRT or audio-visual equipment to enrich the educational experience. However, they allow extra-instructional uses, such as administrative and research functions in the school. Further, such systems could be used by the community to study traffic problems, for example, or delinquency, or demographic data. The possibilities for using a computer through time-sharing are limited only by the languages available, the size of the computer, and the imagination of the users. In addition, the more extensive the use of the system, the less it costs. The ultimate ideal would probably be a completely specialized educational system within a larger time-sharing one.

Questions are beginning to be raised in the field about the possibility of a universal computer language, and about how desirable such a language would be. The present diversity of both hardware and languages may be a necessary stage in the development of an effective medium. Whether a universal language will ever by possible is one of the questions that face us.

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